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(54) MONO DIAMETER WELLBORE CASING

BOHRLOCHFUTTERROHR MIT EINHEITLICHEM DURCHMESSER

TUBAGE DE PUITS DE FORAGE A DIAMETRE UNIQUE

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Description

[0001] This invention relates generally to oil and gas exploration, and in particular to forming and repairing wellbore casings to facilitate oil and gas exploration.

Background of the Invention

[0002] Conventionally, when a wellbore is created, a number of casings are installed in the borehole to prevent collapse of the borehole wall and to prevent undesired outflow of drilling fluid into the formation or inflow of fluid from the formation into the borehole. The borehole is drilled in intervals whereby a casing which is to be installed in a lower borehole interval is lowered through a previously installed casing of an upper borehole interval. As a consequence of this procedure the casing of the lower interval is of smaller diameter than the casing of the upper interval. Thus, the casings are in a nested arrangement with casing diameters decreasing in downward direction. Cement annuli are provided between the outer surfaces of the casings and the borehole wall to seal the casings from the borehole wall. As a consequence of this nested arrangement a relatively large borehole diameter is required at the upper part of the wellbore. Such a large borehole diameter involves increased costs due to heavy casing handling equipment, large drill bits and increased volumes of drilling fluid and drill cuttings. Moreover, increased drilling rig time is involved due to required cement pumping, cement hardening, required equipment changes due to large variations in hole diameters drilled in the course of the well, and the large volume of cuttings drilled and removed.

[0003] WO 02/053867 discloses an apparatus having the pre-characterising features of claim 1.

[0004] The present invention is directed to overcoming one or more of the limitations of the existing procedures for forming and/or repairing wellbore casings.

Summary of the Invention

[0005] According to a first aspect of the present invention there is provided an apparatus for radially expanding and plastically deforming an expandable tubular member, comprising: a support member; an adjustable expansion cone assembly coupled to the support member; an expandable tubular member coupled to the adjustable expansion cone assembly, characterised by: means for displacing the adjustable expansion cone assembly relative to the expandable tubular member and the support member; and means for adjusting the adjustable expansion cone assembly from one effective expansion diameter to another effective expansion diameter.

[0006] According to a second aspect of the present invention there is provided a method of forming a casing in a wellbore, comprising: positioning an expansion device within an expandable tubular member, characterised by: positioning the expansion device and the expandable tubular member into the wellbore; lowering the expansion device out of an end of the expandable tubular member within the wellbore; radially expanding and plastically deforming a lower portion of the expandable tubular member to a first inside diameter using the expansion device; and radially expanding and plastically deforming an upper portion of the expandable tubular member to a second inside diameter using the expansion device, wherein the first inside diameter is larger than the second inside diameter.

Brief Description of the Drawings

[0007] Fig. 1 is a schematic fragmentary cross-sectional illustration of an expandable tubular member and expansion cone assembly running through a mono diameter well bore casing formed according to one aspect to the invention.

[0008] Fig. 2 is a schematic fragmentary cross-sectional illustration of an expandable tubular member and expansion cone assembly forming a bell portion of the mono diameter well bore casing of Fig. 1 according to one aspect to the invention.

[0009] Fig. 3 is a schematic fragmentary cross-sectional illustration of an expandable tubular member and expansion cone assembly forming a mono diameter portion of the mono diameter wellbore casing of Figs. 1 and 2 according to another aspect to the invention.

[0010] Fig. 4 is a schematic fragmentary cross-sectional illustration of an expandable tubular member, a gripping mechanism within the tubular member, an actuator, an expansion cone assembly for forming a mono diameter casing and a float shoe supporting the tubular member for running into a wellbore.

[0011] Fig. 5 is a schematic fragmentary cross-sectional illustration of an expandable tubular member, a gripping mechanism engaging the tubular member, an actuator and expansion cone assembly for forming a mono diameter casing, with the tubular member lifted off the bottom of the wellbore and with the expansion cone assembly pushed by the actuator into an open wellbore.

[0012] Fig. 6 is a schematic fragmentary cross-sectional illustration of the expansion cone assembly expanded for radially expanding and plastically deforming the expandable tubular member.

[0013] Figs. 7a - 7e are fragmentary cross-sectional illustrations of the placement of an exemplary embodiment of an apparatus for forming a mono diameter wellbore casing within a wellbore that traverses a subterranean formation.

[0014] Figs. 8a - 8e are fragmentary cross-sectional illustrations of the apparatus of Figs. 7a - 7e after placement on the bottom of the wellbore.

[0015] Figs. 9a - 9e are fragmentary cross-sectional illustrations of the apparatus of Figs. 8a - 8e after placing a ball or dart within the ball or dart seat to initiate the radial expansion and plastic deformation of the expandable tubular member.

ent application serial no. 60/159,039, attorney docket no. 25791.36, filed on 10/12/1999, (15) U.S. provisional patent application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (16) U.S. provisional patent application serial no. 60/212,359, attorney docket no. 25791.38, filed on 6/19/2000, (17) U.S. provisional patent application serial no. 60/165,228, attorney docket no. 25791.39, filed on 11/12/1999, (18) U.S. provisional patent application serial no. 60/221,443, attorney docket no. 25791.45, filed on 7/28/2000, (19) U.S. provisional patent application serial no. 60/221,645, attorney docket no. 25791.46, filed on 7/28/2000, (20) U.S. provisional patent application serial no. 60/233,638, attorney docket no. 25791.47, filed on 9/18/2000, (21) U.S. provisional patent application serial no. 60/237,334, attorney docket no. 25791.48, filed on 10/2/2000, (22) U.S. provisional patent application serial no. 60/270,007, attorney docket no. 25791.50, filed on 2/20/2001, (23) U.S. provisional patent application serial no. 60/262,434, attorney docket no. 25791.51, filed on 1/17/2001, (24) U.S. provisional patent application serial no. 60/259,486, attorney docket no. 25791.52, filed on 1/3/2001, (25) U.S. provisional patent application serial no. 60/303,740, attorney docket no. 25791.61, filed on 7/6/2001, (26) U.S. provisional patent application serial no. 60/313,453, attorney docket no. 25791.59, filed on 8/20/2001, (27) U.S. provisional patent application serial no. 60/317,985, attorney docket no. 25791.67, filed on 9/6/2001, (28) U.S. provisional patent application serial no. 60/3318,386, attorney docket no. 25791.67.02, filed on 9/10/2001, (29) U.S. utility patent application serial no. 09/969,922, attorney docket no. 25791.69, filed on 10/3/2001, (30) U.S. utility patent application serial no. 10/016,467, attorney docket no. 25791.70, filed on 12/10/2001, (31) U.S. provisional patent application serial no. 60/343,674, attorney docket no. 25791.68, filed on 12/27/2001, (32) U.S. provisional patent application serial no. 60/346,309, attorney docket no 25791.92, filed on 1/7/2002, (33) U.S. provisional patent application serial no. 60/372,048, attorney docket no. 25791.93, filed on 4/12/2002, (34) U.S. provisional patent application serial no. 60/380,147, attorney docket no. 25791.104, filed on 5/6/2002, (35) U.S. provisional patent application serial no. 60/387,486, attorney docket no. 25791.107, filed on 6/10/2002, (36) U.S. provisional patent application serial no. 60/387,961, attorney docket no. 25791.108, filed on 6/12/2002, (37) U.S. provisional patent application serial no. 60/391,703, attorney docket no. 25791.90, filed on 6/26/2002, (38) U.S. provisional patent application serial no. 60/397,284, attorney docket no. 25791.106, filed on 7/19/2002, (39) U.S. provisional patent application serial no. 60/398,061, attorney docket no. 25791.110, filed on 7/24/2002, (40) U.S. provisional patent application serial no, 60/405,610, attorney docket no. 25791.119, filed on 8/23/2002, (41) U.S. provisional patent application serial no. 60/405,394, attorney docket no. 25791.120, filed on 8/23/2002, (42) U.S. provisional patent application serial no. 60/412,177, attorney docket no. 25791.117, filed on 9/20/2002, (43) U.S. provisional patent application serial no. 60/412,653, attorney docket no. 25791.118, filed on 9/20/2002, (44) U.S. provisional patent application serial no. 60/412,544, attorney docket no. 25791.121, filed on 9/20/2002, (45) U.S. provisional patent application serial no. 60/412,187, attorney docket no. 25791.128, filed on 9/20/2002, (46) U.S. provisional patent application serial no. 60/412,187, attorney docket no. 25791.127, filed on 9/20/2002, (47) U.S. provisional patent application serial no. 60/412,487, attorney docket no. 25791.112, filed on 9/20/2002, and (48) U.S. provisional patent application serial no. 60/412,488, attorney docket no. 25791.114, filed on 9/20/2002, the disclosures of which are incorporated herein by reference.

[0030] Fig. 1 shows a schematic illustration of an apparatus 10 in a wellbore 12 with an expandable tubular member 14 and an expansion cone assembly 16 supported by a tubular support 30 (such as a drill pipe 30), all supported by a float shoe 32 for running into a wellbore 12 through a plurality of casing sections 18a and 18b of a mono diameter wellbore casing 18 in the process of being formed, according to one aspect to the invention. The existing casing 18 sections 18a and 18b have been formed from expandable tubular members 14 and according to the teachings of the present invention include mono diameter portions 28a and 28b with a first inside diameter ID1 and bell portions 22a and 22b having a second inside diameter inside diameter ID2 and a length L. There is an overlapping portion 26 where the bell portions 22a overlap of the casing section 18b.

[0031] Fig. 2 shows a schematic illustration of the expandable tubular member 14, acted upon by a large cone 20 of the expansion cone assembly 16 to expand the diameter of the lower end of the expandable tubular member 14 to form a bell portion 22. The bell portion 22 is formed by the large cone 20 of the expansion cone assembly 16 that has an adjustable cone diameter sufficiently large so that the resulting expanded inside diameter of the bell portion 20 is at least slightly larger than a desired inside diameter of the mono diameter wellbore casing 18. The length of the bell portion 20 depends upon the desired length of overlapping lengths 26 between nested casing sections 18a, 18b, and 18c. For example, it is contemplated applicants that the overlap length 26 and therefore the bell portion 22 may have a length up to about 30.5m (100 feet) or up to about 45.7m (150 feet).

[0032] Fig. 3 shows a schematic illustration of the expandable tubular member 14 of Fig. 2, with the expansion cone assembly 16 positioned for expanding the expandable tubular member 14 to the desired mono diameter at the portion 28 above the bell portion 22. In this configuration the diameter of the large adjustable cone 20 is collapsed, or is other wise adjusted, to a smaller diameter. Another cone 24, having a diameter smaller than the large diameter of cone 20, is provided for radially expanding the tubular member 14 to the desired inside diameter of the mono diameter wellbore casing. The wellbore casing section 18c of the mono diameter well bore casing 18 of Figs. 1 and 2, overlaps with the wellbore casing

[0016] Figs. 10a - 10e are fragmentary cross-sectional illustrations of the apparatus of Figs. 9a-9e after the initiation of the radial expansion and plastic deformation of the aluminum sleeve within the shoe.

[0017] Fig. 11a - 11b is a fragmentary cross-sectional illustration of an exemplary embodiment of an apparatus for radially expanding and plastically deforming a tubular member that includes an adjustably expandable expansion cone assembly.

[0018] Fig. 12 is a fragmentary cross-sectional illustration of an upper cone portion of the apparatus for radially expanding and plastically deforming a tubular member of Figs. 11a - 11b.

[0019] Fig. 13 is a fragmentary cross-sectional illustration of a lower cone portion of the apparatus for radially expanding and plastically deforming a tubular member of Figs. 11a-11b.

[0020] Fig. 14 is a fragmentary cross-sectional illustration of an overlapping portion of the apparatus for radially expanding and plastically deforming a tubular member of Figs. 11a - 11b, 12 and 13.

[0021] Fig. 15 is a fragmentary cross-sectional and perspective illustrations of the upper cam assembly of the apparatus for radially expanding and plastically deforming a tubular member of Figs. 11a - 11b.

[0022] Fig. 16 is a fragmentary cross-sectional and perspective illustrations of the lower cam assembly of the apparatus for radially expanding and plastically deforming a tubular member of Figs. 11a - 11b.

[0023] Fig. 17a - 17b is a fragmentary cross-sectional illustration of an exemplary embodiment of an apparatus for radially expanding and plastically deforming a tubular member that includes an adjustably expandable expansion cone assembly of Figs. 11a - 11b activated for cementing.

[0024] Fig. 18a - 18b is a fragmentary cross-sectional illustration of an exemplary embodiment of an apparatus for radially expanding and plastically deforming a tubular member that includes an adjustably expandable expansion cone assembly of Figs. 11a - 11b activated for adjusting the expansion diameter.

[0025] Fig. 19 is a fragmentary cross-sectional illustration of an overlapping portion of the apparatus for radially expanding and plastically deforming a tubular member adjusted to an intermediate expansion diameter.

[0026] Fig. 20a - 20b are fragmentary cross sectional illustrations of the apparatus of Figs. 10d-10e after the completion of the radial expansion and plastic deformation of the aluminum sleeve within the shoe.

[0027] Figs. 21a - 21b are fragmentary cross-sectional illustrations of the apparatus of Figs. 20a - 20b after displacing the sliding sleeve valve within the shoe to permit circulation around the ball or dart.

[0028] Figs. 22a - 22b are fragmentary cross sectional illustrations of the apparatus of Figs. 21a - 21b during the injection of cement into the annulus between the radially expanding tubular member and the wellbore using the bypass circulation provided by the displaced sliding sleeve valve within the shoe.

Detailed Description of the Illustrative Embodiments

[0029] Figs. 1- 6 illustrate several illustrative embodiments of a device and method for forming a mono diameter well bore casing using an expansion assembly including two cone diameters, one of which is larger than the other for forming a bell (sometimes called a skirt) section for overlapping expandable tubular members so that the effort required for the expansion assembly to expanded two overlapping tubular members is reduced. The other cone diameter is sized for expanding the tubular members to the desired diameter along the length of the tubular member thereby resulting in a mono-diameter well bore casing. The two diameters may be provided with a conventional adjustable size expansion cone having two expansion diameters, one larger than the other. The larger diameter is adjusted to a smaller diameter after a bell section of an expandable tubular member is formed and then the remainder of the expandable tubular member is expanded to a the desired internal diameter for the mono diameter well bore casing. Conventional adjustably expandable cones can be used according to the invention. In several alternative embodiments, the invention is implemented as described in Figs. 7a - 7e, 8a - 8e, 9a - 9e, 10a - 10e, 11a - 11b and 17a-17b, 18a-18b and 19a-19b with an exemplary adjustably expandable cone assembly as described in greater detail herein with reference to Figs. 11a - 11b, 12, 13, 14, 15 and 16. In other alternative embodiments the adjustably expandable cones of the invention may be implemented or using the methods and/or apparatus disclosed one or more of the following: (1) U.S. patent application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, (2) U.S. patent application serial no. 09/510,913, attorney docket no. 25791.7.02, filed on 2/23/2000, (3) U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, (4) U.S. patent no. 6,328,113, (5) U.S. patent application serial no. 09/523,460, attorney docket no. 25791.11.02, filed on 3/10/2000, (6) U.S. patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, (7) U.S. patent application serial no. 09/511,941, attorney docket no. 25791.16.02, filed on 2/24/2000, (8) U.S. patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, (9) U.S. patent application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, (10) PCT patent application serial no. PCT/US00/18635, attorney docket no. 25791.25.02, filed on 7/9/2000, (11) U.S. provisional patent application serial no. 60/162,671, attorney docket no. 25791.27, filed on 11/1/1999, (12) U.S. provisional patent application serial no. 60/154,047, attorney docket no. 25791.29, filed on 9/16/1999, (13) U.S. provisional patent application serial no. 60/159,082, attorney docket no. 25791.34, filed on 10/12/1999, (14) U.S. provisional pat-

section 18b along the overlapping length 26 and at the bell portion 22b. The inside diameter or the bell portion 22 and the outside diameter of the mono diameter portion 28 are the same to provide a tight fitting junction between the nested sections 18a, b, c and etc. For example, where the expandable tubular member 14 has a wall thickness of about 0.35 inches and for the desired inside diameter of the mono diameter wellbore casing is about 10.3 inches, after expansion, the inside diameter of the bell portion might be about 11.0 inches, or slightly less to provide a tight fit between the overlapping portions of the casing sections 18a, b, c and etc.

[0033] The large diameter cone 20 can be positioned above, below or effectively at the same position as the small diameter cone 24, without departing from certain aspects of the invention. Also, it will be understood by those of ordinary skill in the art, and based upon this disclosure, that the large diameter corresponding to the inside diameter of the bell portion can be provided by a first collapsible or adjustable cone 22, that provides the desired bell portion diameter and that can be collapsed to a smaller diameter, together with a second cone 24 that provides the diameter for forming the mono diameter well bore casing. It will also be understood that in an alternative embodiment the expansion to the mono diameter can be provided by adjusting the diameter of cone 22 to effectively become the smaller diameter cone 24 having a diameter corresponding to the desired mono diameter. It will further be understood that in another alternative embodiment the cone 24 is a distinct cone 24 either fixed at the desired mono diameter size or expandable to the desired mono diameter size.

[0034] Fig. 4 shows a schematic mono diameter casing forming apparatus 10, further depicting one arrangement of a mechanism for activating the expansion cone assembly 16 to expand the tubular member 14. The apparatus 10 is shown in a configuration for running into a wellbore 12. A drill pipe 30 supports the apparatus 10, as it is running down into the wellbore 12, with a connected float shoe 32. The drill pipe 30 may be a conventional drill pipe or other conventional down hole tubular support member. The float shoe may be a conventional float shoe or other tool guiding structure that serves the describe purpose attached to the drill pipe or other tubular support member. The float shoe 32 thus supports the new expandable tubular member 14 that is to be added to and expanded for engagement with the lower end of the mono diameter wellbore casing 18 that has been previously formed. An gripping tool 34, sometimes called an anchor that may be a device as shown or a conventional gripping tool or anchor, is provided to hold the expandable tubular member 14 fixed relative to one end of a hydraulic actuator 36, sometimes called a force multiplier mechanism that may be a device as shown or a conventional actuator or force multiplier. The hydraulic actuator 36 is configured and actuatable for moving the expansion cone assembly 16 relative to the expandable member 14, either in tension using sub 36a or in compression using sub 36b.

[0035] Fig. 5 schematically shows an embodiment of the mono diameter casing forming apparatus 10, with the gripping mechanism 34 engaging the tubular member 14, with the tubular member 14 lifted off the bottom of the well bore 12 and with the expansion cone 16 pushed by actuator 36 into the open wellbore 12. A conventional dart 53 or ball is dropped to seal the float shoe 32, or another conventional shut-off device such as a mechanical valve or a velocity valve is used and activated, so that fluid 38 forced through the drill pipe 22 increases pressure to activate the gripping tool 26. When the drill pipe 22 is set down at the bottom of the hole, the tension sub 36a of the actuator mechanism 36 is actuated. Pressure is increased in the drill pipe 30 and the gripping mechanism 34 is engaged to anchor the tubular member 14. Compression sub 36b is activated to lift the tubular liner 14 off the bottom of the wellbore and to push the cone assembly 16 into the open hole of wellbore 12.

[0036] Fig. 6 shows the expansion cone assembly 16 expanded for radially expanding and plastically deforming the expandable tubular member 14. The expansion of the expansion cone assembly is activated in a conventional manner, as with a dart 42 that is passed with the fluid 38 down through the drill pipe 30 to thereby cause appropriate port alignment and/or appropriate valve activation for the expansion cone assembly 16. An optional sacrificial protective sleeve 40 that protects the expansion cone assembly 16 while it is running into the wellbore breaks off when the expansion cone assembly is expanded. The protective sleeve 40 may be formed of a plastic or composite material so that the sacrificial protective sleeve easily breaks off and does not interfere with the expansion of the tubular member 14.

[0037] In an exemplary embodiment, as illustrated in Figs. 7a -7e, an apparatus 10 for forming a mono diameter wellbore casing 18 is positioned within a wellbore 12. The apparatus 10 includes, among other things, an expandable tubular member 14 and an adjustable expansion cone assembly 16. During placement of the apparatus 10 within the wellbore 12, the expandable tubular member 14 may be supported by the grip tool 34 and/or the expansion cone assembly 16 and/or the float shoe 32.

[0038] In an exemplary embodiment, as illustrated in Figs. 8a - 8e, the apparatus 10 is then positioned into contact with the bottom 44 of the wellbore 12. As a result, a shear pin 46 is sheared and a dog locking sleeve 48 is driven upwardly thereby displacing a plurality of dogs 50 outwardly in the radial direction in a conventional manner.

[0039] In an exemplary embodiment, as illustrated in Figs. 9a - 9e, a ball 52 or conventional dart may then be placed within the ball or dart seat 54 of the apparatus by injecting fluidic material 38 into the apparatus 10. As a result, the flow of fluidic material 38 through the float shoe 32 is blocked. The expansion cone assembly is also actuated in a conventional manner, for example with the pressure caused by the ball 52 or a dart 42 (as shown in Fig. 6 above), to expand to the large diameter for expanding the bell. Pressure builds and the actuator 36 is

activated in tension to draw the large cone 20 upward partially through the expandable tubular member 14. Pressure can be released and reactivated in the actuator 36 and gripping tool 34 to repeatedly stroke the large cone 20 of the expansion cone assembly 16 along the desired overlapping length L of the casing to thereby form the bell portion 22 of the casing.

[0040] In an exemplary embodiment, as illustrated in Figs. 10a - 10e, the large diameter cone 20 is actuated to collapse or adjust to a smaller diameter cone 24 corresponding to the desired diameter of the mono diameter casing 18, using conventional actuation, for example, increased fluidic pressure and a rupture disc in an appropriate port (not shown) or an additional dart 56 injected with the fluidic material 38 into the apparatus 10 to a conventional dart seat 58. The gripping tool 34 is activated to lock the top end of the hydraulic actuator 36 to the expandable tubular member 14. The injected fluidic material 38 also causes the adjustable cone 24 to reach the desired diametrical size for forming the mono diameter casing 18. The continued injection of the fluidic material 38 furthermore increases the operating pressure within the apparatus thereby causing the hydraulic actuator 36 to pull the expansion cone 24 into the expandable tubular member 14. As a result, the expandable tubular member 14 is radially expanded.

[0041] The continued upward movement of the expansion cone pulls the float shoe 32 to the bottom end of the radially expanded tubular member 14. As a result, the end of the radially expanded tubular member 14 will impact the dogs 50 thereby preventing the float shoe 32 from moving further in the upward direction. The continued upward movement of the expansion cone then will pull a sleeve expander cone 60 for the sleeve 62 upwardly thereby radially expanding a sleeve of the float shoe within the float shoe.

[0042] In one exemplary embodiment, as illustrated in Figs. 11 a - 11 b, 12, 13, 14, 15 and 16, the expansion cone assembly 16 is adjustable for providing two outside diameters, one outside diameter larger than the other outside diameter. The construction of the expandable cone assembly may also be constructed in accordance with the principles and design disclosed in U.S. provisional patent application serial no. 60/387,961, attorney docket no. 25791.108, filed on 6/12/2002, the disclosure of which is incorporated herein by reference. An exemplary embodiment includes a tubular support member 64 coupled to an end of a safety collar 66 that defines a passage 66a and a recess 66b, at one end for receiving the end of the tubular support member 14, and recesses 66c and 66d at another end.

[0043] A torque plate 68 is received within and is coupled to the recess 66c of the safety collar 66 that defines a passage 68a and a plurality of meshing teeth 68b at one end. An end of an upper mandrel collar 70 is received with and is coupled to the recess 66d of the safety collar 66 proximate an end of the torque plate 68 that defines a passage 68a. Torque pins 72a and 72b further couple the end of the upper mandrel collar 70 to the end of the safety collar 66.

[0044] An end of an upper mandrel 74 is received within and is coupled to the upper mandrel collar 70 that defines a passage 74a, a plurality of meshing teeth 74b that mate with and transmit torque to and from the meshing teeth 68b of the torque plate 68, and an external flange 74c at another end.

[0045] An upper packer cup 76 mates with, receives and is coupled to the upper mandrel 74 proximate the end of the upper mandrel collar 70. In an exemplary embodiment, the upper packer cup 76 is a conventional Guiberson™ packer cup. An upper spacer sleeve 78 mates with, receives, and is coupled to the upper mandrel 74 proximate an end of the upper packer cup 76. A lower packer cup 80 mates with, receives and is coupled to the upper mandrel 74 proximate an end of the upper spacer sleeve 78. In an exemplary embodiment, the lower packer cup 80 is a conventional Guiberson™ packer cup. A lower spacer sleeve 82 mates with, receives, and is coupled to the upper mandrel 74 proximate an end of the lower packer cup 80 and the external flange 74c of the upper mandrel. A retaining sleeve 84 mates with, receives, and is coupled to an end of the lower spacer sleeve proximate the external flange 74c of the upper mandrel 74.

[0046] An end of a lower mandrel 86 defines a recess 86a that mates with, receives, and is coupled to the external flange 74c of the upper mandrel 74, a recess 86b that mates with, receives, and is coupled to the end of the upper mandrel, a passage 86c, and an external flange 86d including circumferentially spaced apart meshing teeth 86da on an end face of the external flange. Torque pins 88a and 88b further couple the recess 86a of the end of the lower mandrel 86 to the external flange 74c of the upper mandrel 74. During operation, the torque pins 88a and 88b transmit torque loads between the recess 86a of the end of the lower mandrel 86 and the external flange 74c of the upper mandrel 74.

[0047] An upper cam assembly 90 includes a tubular base 90a for receiving and mating with the lower mandrel 86 that includes an external flange 90aa, a plurality of circumferentially spaced apart meshing teeth 90b that extend from one end of the tubular base in the longitudinal and radial directions for engaging the meshing teeth 86da of the end face of the external flange 86d of the lower mandrel 86, and a plurality of circumferentially spaced apart cam arms 90c that extend from the other end of the tubular base in the opposite longitudinal direction and mate with and receive the lower mandrel 86. During operation, the meshing teeth 86da of the end face of the external flange 86d of the lower mandrel 86 transmit torque loads to the meshing teeth 90b of the upper cam assembly 90. Each of the cam arms 90c include an inner portion 90ca extending from the tubular base 90a that has arcuate cylindrical inner 90caa and outer 90cab surfaces, a tapered intermediate portion extending from the inner portion 90cb that has an arcuate cylindrical inner

surface 90cba and an arcuate conical outer surface 90bbb, and an outer portion 90cc extending from the intermediate portion 90cc that has arcuate cylindrical inner 90cca and outer surfaces 90ccb.

[0048] A lower cam assembly 92 includes a tubular base 92a for receiving and mating with the lower mandrel 86 that includes an external flange 92aa, a plurality of circumferentially spaced apart meshing teeth 92b that extend from one end of the tubular base in the longitudinal and radial directions, and a plurality of circumferentially spaced apart cam arms 92c that extend from the other end of the tubular base in the opposite longitudinal direction and mate with and receive the lower mandrel 86. Each of the cam arms 92c include an inner portion 92ca extending from the tubular base 92a that has arcuate cylindrical inner 92caa and outer 92cab surfaces, a tapered intermediate portion 92cb extending from the inner portion 92ca that has an arcuate cylindrical inner surface 92cba and an arcuate conical outer surface 92cbb, and an outer portion 92cc extending from the intermediate portion 92cb that has arcuate cylindrical inner 92cca and outer 92ccb surfaces.

[0049] In an exemplary embodiment, the upper and lower cam assemblies, 90 and 92, are substantially identical. In an exemplary embodiment, the cam arms 90c of the upper cam assembly 90 interleave the cam arms 92c of the lower cam assembly 92. Furthermore, in an exemplary embodiment, the cam arms 90c of the upper cam assembly also overlap with the cam arms 92c of the lower cam assembly 92 in the longitudinal direction thereby permitting torque loads to be transmitted between the upper and lower cam assemblies.

[0050] A plurality of upper expansion cone segments 96 are interleaved among the cam arms 90c of the upper cam assembly 90. Each of the upper expansion cone segments 96 include inner portions 96a having arcuate cylindrical inner surfaces 96aa, and an arcuate cylindrical outer surface 96ab, intermediate portions 96b extending from the interior portions that have an arcuate conical inner surface 96ba and arcuate cylindrical and spherical outer surfaces, 96bb, and outer portions 96c having arcuate cylindrical inner and outer surfaces, 96ca and 96cb. In an exemplary embodiment, the outer surfaces 96ab of the inner portions 96a of the upper expansion cone segments 96 define hinge grooves 96d that receive and are pivotally mounted upon the internal flange 94d of the upper retaining sleeve 94.

[0051] The arcuate inner cylindrical surfaces of the inner portion 96a mate with and receive the lower mandrel 86, the arcuate inner cylindrical surfaces of the inner portion 96a also mate with and receive the arcuate cylindrical outer surfaces of the outer portions 92cc of the corresponding cam arms 92c of the lower cam assembly 92, and the arcuate inner conical surfaces 96ba of the inner portion 96a mate with and receive the arcuate conical outer surfaces of the intermediate portions 92cb of the corresponding cam arms 92c of the lower cam assembly 92.

[0052] A plurality of lower expansion cone segments 98 are interleaved among, and overlap, the upper expansion cone segments 96 and the cam arms 90c of the lower cam assembly 90. In this manner, torque loads may be transmitted between the upper and lower expansion cone segments, 96 and 98. Each of the lower expansion cone segments 98 include inner portions 98a having arcuate cylindrical inner surfaces, 98aa, and an arcuate cylindrical outer surface 98ab, intermediate portions 98b extending from the interior portions that have an arcuate conical inner surface 98ba and arcuate cylindrical and spherical outer surfaces, 98bb, and outer portions 98c having arcuate cylindrical inner and outer surfaces, 98ca and 98cb. In an exemplary embodiment, the outer surfaces 98ab of the inner portions 98a of the upper expansion cone segments 98 define hinge grooves 98aba that receive and are pivotally mounted upon the internal flange 100d of a lower retaining sleeve 100.

[0053] The arcuate inner cylindrical surfaces 98aa mate with and receive the lower mandrel 86, the arcuate inner cylindrical surfaces 98aa also mate with and receive the arcuate cylindrical outer surfaces of the outer portions 90cc of the corresponding cam arms 90c of the upper cam assembly 90, and the arcuate inner conical surfaces 98ba mate with and receive the arcuate conical outer surfaces of the intermediate portions 90cb of the corresponding cam arms 90c of the lower cam assembly 90.

[0054] In an exemplary embodiment, the geometries of the upper and lower expansion cone segments 96 and 98 are substantially identical. In an exemplary embodiment, the upper expansion cone segments 96 are tapered in the longitudinal direction from the ends of the intermediate portions 96b to the ends of the outer portions 96c, and the lower expansion cone segments 98 are tapered in the longitudinal direction from the ends of the intermediate portions 98b to the ends of the outer portions 98c. In an exemplary embodiment, when the upper and lower expansion segments, 96 and 98, are positioned in a fully expanded position, the arcuate cylindrical outer surfaces 96ab of the upper and lower expansion cone segments 96 define a contiguous cylindrical surface, the arcuate spherical outer surfaces of the upper and lower expansion cone segments, 96bb and 98bb, define a contiguous arcuate spherical surface, and the arcuate cylindrical outer surfaces of the upper and lower expansion cone segments define a contiguous cylindrical surface.

[0055] An end of a lower retaining sleeve 100 defines a passage 100a for receiving and mating with the outer circumferential surfaces of the external flange 92aa and the meshing teeth 92b of the lower cam assembly 92, and an inner annular recess 100b, and includes an internal flange 100c for retaining the external flange of the lower cam assembly, and an internal flange 100d at one end of the lower retaining sleeve that includes a rounded interior end face for mating with corresponding hinge grooves of the lower expansion cone segments 98 thereby pivotally coupling the lower expansion cone segments

to the lower retaining sleeve.

[0056] In an exemplary embodiment, the arcuate cylindrical outer surfaces of the upper expansion cone segments 96 and the arcuate cylindrical outer surfaces of the lower expansion cone segments 98 are aligned with the outer surface of the upper retaining sleeve 94. In an exemplary embodiment, the arcuate cylindrical outer surfaces of the upper expansion cone segments 96 and the arcuate cylindrical outer surfaces of the lower expansion cone segments are aligned with the outer surface of the lower retaining sleeve 100.

[0057] An end of a float shoe adaptor 102 that includes a plurality of circumferentially spaced apart meshing teeth 102a for engaging the meshing teeth 92b of the lower cam assembly 92 is received within and threadably coupled to an end of the lower retaining sleeve 100 that defines a passage 102b at one end for receiving an end of the lower mandrel 86, a passage 102c having a reduced inside diameter at another end, a plurality of radial passages 102d at the other end, and includes an internal flange 102e, and a torsional coupling 102f at the other end that includes a plurality of torsional coupling members 102fa. During operation, the meshing teeth 92b of the lower cam assembly 92 transmit toque loads to and from the meshing teeth 102a of the float shoe adaptor.

[0058] An end of a retaining sleeve 104 abuts the end face of the tubular base 92a of the lower cam assembly 92 and is received within and mates with the passage 102b of the float shoe adaptor 102 that defines a passage 104a for receiving an end of the lower mandrel 86, a throat passage 104b including a ball valve seat 104c, and includes a flange 104d, and another end of the retaining sleeve, having a reduced outside diameter, is received within and mates with the passage 102c of the float shoe adaptor 102.

[0059] A stop nut 106 receives and is threadably coupled to the end of the lower mandrel 86 within the passage 104a of the retaining sleeve 104, and shear pins 108 releasably couple the stop nut 106 to the retaining sleeve 104. Locking dogs 110 are positioned within an end of the retaining sleeve 104 that receive and are releasably coupled to the lower mandrel 86, and a disc shaped adjustment shim 112 receives the lower mandrel 86 and is positioned within an end of the retaining sleeve 104 between the opposing ends of the tubular base 92a of the upper cam assembly 92 and the locking dogs 110. Burst discs 114 are releasably coupled to and positioned within the radial passages 102d of the float shoe adaptor 102.

[0060] An end of a float shoe 116 mates with and is releasably coupled to the torsional coupling 102f of the float shoe adaptor 102 that defines a passage 116a and a valveable passage 116b. In this manner torsional loads may be transmitted between the float shoe adaptor 102 and the float shoe 116. An end of an expandable tubular member 14 that surrounds the tubular support member 64, the safety collar 66, the upper mandrel collar 70, the upper packer cup 76, the lower packer cup 80, the lower mandrel 86, the upper expansion cone segments 96, the lower expansion cone segments 98, and the float shoe adaptor 102, is coupled to and receives an end of the float shoe 116 and is movably coupled to and supported by the arcuate spherical external surfaces, 96bb and 98bb, of the upper and lower expansion cone segments, 96 and 98.

[0061] During operation, the apparatus 10 is at least partially positioned within a preexisting structure such as, for example, a borehole 12 that traverses a subterranean formation that may include a preexisting wellbore casing 18. The borehole 12 may be oriented in any position, for example, from vertical to horizontal. A fluidic material 38 is then injected into the apparatus 10 through the passages 64a, 66a, 74a, 86c, 102c, 116a, and 116b into the annulus between the expandable tubular member 14 and the borehole 12. In an exemplary embodiment, the fluidic material 104 is a hardenable fluidic sealing material. In this manner, an annular sealing layer may be formed within the annulus between the expandable tubular member 14 and the borehole 12.

[0062] As illustrated in Figs. 17a and 17b, a ball 55 is then be positioned within and blocking the valveable passage 116b of the float shoe 116 by injecting a fluidic material 38 into the apparatus 10 through the passages 64a, 66a, 74a, 86c, and 102c. As a result, the increased operating pressure within the passage 102c bursts open the burst discs 114 positioned within the radial passages 102d of the float shoe adaptor 102. The continued injection of the fluidic material 38 thereby pressurizes the interior of the expandable tubular member 14 below the lower packer cup 80 thereby displacing the upper and lower expansion cone segments, 96 and 98, upwardly relative to the float shoe 116 and the expandable tubular member 14. As a result, the expandable tubular member 14 is plastically deformed and radially expanded. Thus, the burst discs 114 sense the operating pressure of the injected fluidic material 38 within the passage 102c and thereby control the initiation of the radial expansion and plastic deformation of the expandable tubular member 14.

[0063] In an exemplary embodiment, any leakage of the pressurized fluidic material 38 past the lower packer cup 80 is captured and sealed against further leakage by the upper packer cup 76. In this manner, the lower packer cup 80 provides the primary fluidic seal against the interior surface of the expandable tubular member 14, and the upper packer cup 76 provides a secondary, back-up, fluidic seal against the interior surface of the expandable tubular member. Furthermore, because the lower packer cup 80 and/or the upper packer cup 76 provide a fluid tight seal against the interior surface of the expandable tubular member 14, the upper and lower expansion cone segments, 96 and 98, are pulled upwardly through the expandable tubular member by the axial forces created by the packer cups.

[0064] In an exemplary embodiment, during the radial expansion process, the interface between the arcuate spherical external surfaces, 96bb and 98bb, of the upper

and lower expansion cone segments, 96 and 98, and the interior surface of the expandable tubular member 14 is not fluid tight. As a result, the fluidic material 38 may provide lubrication to the entire extent of the interface between the cylindrical external surfaces, 96bba and 98cb, and the arcuate spherical external surfaces, 96bb and 98bb, of the upper and lower expansion cone segments, 96 and 98, and the interior surface of the expandable tubular member 14. Moreover, experimental test results have indicated the unexpected result that the required operating pressure of the fluidic material 38 for radial expansion of the expandable tubular member 14 is less when the interface between the cylindrical external surfaces, 96bba and 98cb, and the arcuate spherical external surfaces, 96bb and 98bb, of the upper and lower expansion cone segments, 96 and 98, and the interior surface of the expandable tubular member 14 is not fluid tight. Furthermore, experimental test results have also demonstrated that the arcuate spherical external surface provided by the arcuate spherical external surfaces, 96bb and 98bb, of the upper and lower expansion cone segments, 96 and 98, provides radial expansion and plastic deformation of the expandable tubular member 14 using lower operating pressures versus an expansion cone having a conical outer surface.

[0065] In an exemplary embodiment, as illustrated in Figs. 18a, 18b and 19, the upper and lower expansion cone segments, 96 and 98, may then be adjusted to a desired expansion diameter by placing a ball 57 within the ball valve seat 104c of the throat passage 104b of the retaining sleeve 104. The continued injection of the fluidic material 38, after the placement of the ball 57 within the ball valve seat 104c, creates a differential pressure across the ball 57 thereby applying a downward longitudinal force onto the retaining sleeve 104 thereby shearing the shear pins 108. As a result, the retaining sleeve 104 is displaced in the downward longitudinal direction relative to the float shoe adaptor 102 thereby permitting the locking dogs 110 to be displaced outwardly in the radial direction. The outward radial displacement of the locking dogs 110 disengages the locking dogs from engagement with the lower mandrel 86. Thus, the shear pins 108 sense the operating pressure of the injected fluidic material 38 within the throat passage 104b and thereby controlling the initiation of the collapsing of the upper and lower expansion cone segments, 96 and 98 to a smaller diameter.

[0066] The continued injection of the fluidic material 38 continues to -displace the retaining sleeve 104 in the downward longitudinal direction relative to the float shoe adaptor 102 until the external flange 104d of the retaining sleeve 104 impacts, and applies a downward longitudinal force to, the internal flange 102e of the float shoe adaptor. As a result, the float shoe adaptor 102 is then also displaced in the downward longitudinal direction relative to the lower mandrel 86. The downward longitudinal displacement of the float shoe adaptor 102 relative to the lower mandrel 86 causes the lower cam assembly 92, the lower expansion cone segments 98, and the lower retaining sleeve 100, which are rigidly attached to the float shoe adaptor, to also be displaced downwardly in the longitudinal direction relative to the lower mandrel 86, the upper cam assembly 90, and the upper expansion cone segments 96. The downward longitudinal displacement of the lower cam assembly 92 relative to the upper expansion cone segments 96 causes the upper expansion cone segments to slide down the conical external surfaces 92cbb of the lower cam assembly and thereby pivot inwardly in the radial direction about the internal flange 94d of the upper retaining sleeve 94. The downward longitudinal displacement of the lower expansion cone segments 98 relative to the upper cam assembly 90 causes the lower expansion cone segments 98 to slide down the external conical surfaces 90cbb of the upper cam assembly and thereby pivot inwardly in the radial direction about the internal flange 100d of the lower retaining sleeve. As a result of the inward radial movement of the upper and lower expansion cone segments, 96 and 98, the arcuate external spherical surfaces, 96bb and 98bb, of the upper and lower expansion cone segments, 96 and 98, provide outer arcuate expansion surfaces having a smaller diameter.

[0067] The downward longitudinal movement of the retaining sleeve 94 and float shoe adaptor 102 relative to the lower mandrel 86 is stopped when the stop nut 106 impacts the locking dogs 110. At this point, the apparatus 10 may then be removed from the interior of the expandable tubular member 14.

[0068] Thus, the apparatus 10 may be removed from the expandable tubular member 14 prior to the complete radial expansion and plastic deformation of the expandable tubular member by controllably collapsing the upper and lower expansion cone segments, 96 and 98. As a result, the apparatus 10 provides the following benefits: (1) the apparatus is removable when expansion- problems are encountered; (2) lower expansion forces are required because the portion of the expandable tubular member 14 between the packer cups, 76 and 80, and the expansion cone segments is exposed to the expansion fluid pressure; (3) the expansion cone segments can be run down through the expandable tubular member, prior to radial expansion, and then the expansion cone segments can be expanded; (4) the expansion cone segments can be expanded to one diameter for forming a bell portion; and (5) the expansion cone segments can be adjusted to a second diameter for expanding the remainder of the expandable tubular member.

[0069] In another exemplary embodiment, as illustrated in Figs. 20a - 20b, upward movement of the apparatus 10 causes the expansion cone for the sleeve 60 to completely radially expand the sleeve 62 of the float shoe 32 and a cementing probe 118 is pulled downward until stopped from further movement by the cementing probe locking ring 119. As a result of the complete radial expansion of the sleeve, the float - shoe is now firmly coupled to the end of the radially expanded-tubular member.

[0070] In an exemplary embodiment, as illustrated in Figs. 21a -21b, the drill pipe 30 is lowered into the wellbore 12 until the cementing probe 118 stabs into the end 120 of the sliding sleeve valve 122 thereby permitting fluidic materials 38 to bypass around the dart or ball 52. As a result, a bypass flow path 124 is now provided for cement or other fluidic materials 38 to flow around the ball 52 or dart.

[0071] In an exemplary embodiment, as illustrated in Figs. 22a -22b, a hardenable fluidic sealing material 38 such as, for example, cement, may then be injected into the apparatus 10. The cement flows through the interior of the apparatus, through the bypass flow path 124, and out through the float valve 126 into the annulus 128 between the radially expanded tubular member 22 and the wellbore 12. After the cement 38 has been injected into the annulus 128, the float valve 126 prevents the cement from flowing backwards into the apparatus.

[0072] After completing the injection of the cement into the annulus, the drilling pipe 30 is then pulled upwardly out of the wellbore 12 thereby causing the cementing probe 118 to close the sliding sleeve valve 122. The radial expansion and plastic deformation of the expandable tubular member 14 may then be continued by the resumed injection of fluidic material 38 into the apparatus 10. In several alternative embodiments, the continued radial expansion and plastic deformation of the expandable tubular member 14 may be provided by pressurizing the interior of the apparatus 10 below the expansion cone 24 and/or by displacing the expansion cone 24 upwardly using the hydraulic actuator 36.

[0073] After the cement has cured, the float collar 32 may be drilled out and another expandable tubular member may then be radially expanded and plastically deformed within the wellbore with the upper end of the other tubular member overlapping with the lower end of the earlier expanded tubular member. In this manner, a mono diameter well bore casing may be formed that includes a plurality of radially expanded tubular members.

[0074] In several alternative embodiments, Guiberson™ cup seals may be added above the expansion cone that provide a fluid tight seal between the drill pipe and the interior surface of the expandable tubular member. In this manner, in the alternative embodiment, the fluid pressure below the cup seals pulls the expansion cone upwardly through the expandable tubular member.

[0075] In several alternative embodiments, the expandable adjustable expansion cone assembly having two adjustable expansion diameters may be replaced with two separate adjustable cones one adjustable to a diameter corresponding to the desired bell portion diameter, and the other adjustable to a diameter corresponding to the desired diameter of the mono diameter casing.

[0076] In several alternative embodiments, the expandable adjustable expansion cone assembly having two adjustable expansion diameters may be replaced with an adjustable cone that is adjustable to a diameter corresponding to the desired bell portion diameter, and a non-adjustable cone having a fixed diameter corresponding to the desired diameter of the mono diameter casing.

[0077] In several alternative embodiments, a conventional rotary expansion device, a conventional compliant expansion device, and/or a conventional hydroforming expansion device may used instead of, or in combination with, the expansion cone assembly 16.

[0078] In several alternative embodiments, one or more of the conventional commercially available expansion devices available from Weatherford International, Baker Hughes, Halliburton Energy Services, Schlumberger, and/or Enventure Global Technology may be used instead of, or in combination with, the expansion cone assembly 16.

[0079] There has been disclosed in the several embodiments, an apparatus for radially expanding and plastically deforming an expandable tubular member from an initial inside diameter to a desired diameter of a mono diameter wellbore casing. The apparatus includes an upper tubular support member defining a first passage, one or more cup seals coupled to the exterior surface of the upper tubular support member for sealing an interface between the upper tubular support member and the expandable tubular member, an expansion cone assembly coupled to the upper tubular support member adjustable to one expansion diameter corresponding to the desired diameter of the bell portion of the wellbore casing for forming an expanded bell portion in the expandable tubular member and adjustable to another expansion diameter corresponding to the desired diameter of the mono diameter casing for forming the mono diameter wellbore casing, means for actuating the expandable tubular member to adjust from the one diameter to the other diameter, and an actuator for moving the cone through the expandable tubular member a desired distance with the expansion cone assembly adjusted to the diameter of the bell portion and for moving the expansion cone assembly through the expandable tubular member for another distance with the expansion cone assembly adjusted to the desired diameter of the mono diameter portion of the expandable tubular member.

[0080] In one embodiment the expansion cone assembly includes one adjustable cone having an external surface adjustable to the diameter of the bell portion of the expandable tubular member; and wherein the external surface of the one adjustable cone is also adjustable to the diameter corresponding to the desired diameter of the mono diameter wellbore casing.

[0081] In another embodiment the expansion cone assembly includes a first adjustable cone having an external surface adjustable to the diameter of the bell portion of the expandable tubular member and a second adjustable cone having an external surface adjustable to the diameter corresponding to the desired diameter of the mono diameter wellbore casing.

[0082] In another embodiment the expansion cone assembly includes a first adjustable cone having an exter-

nal surface adjustable to the diameter of the bell portion of the expandable tubular member and collapsible after expanding the bell portion and a second cone having a fixed diameter corresponding to the desired diameter of the mono diameter wellbore casing such that collapsing the first cone effectively adjusts the effective expansion diameter to the fixed diameter of the second cone.

[0083] In another embodiment the expansion cone assembly includes an upper cam assembly coupled to the upper tubular support member includes a tubular base coupled to the upper tubular support member; and a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface, a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the tubular support member, and each upper expansion segment movable relative to the inclined surface of one of the plurality of cam arms to adjust the radial position of an eternal surface of the segment to adjust the diameter of the expansion cone assembly, a lower tubular support member defining a second passage fluidicly coupled to the first passage releasably coupled to the upper tubular support member, a lower cam assembly coupled to the lower tubular support member including a tubular base coupled to the lower tubular support member and a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments, wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly; and a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly and each lower expansion segment movable relative to the inclined surface of one of the plurality of cam arms to adjust the radial position of an eternal surface of the segment to adjust the diameter of the expansion cone assembly, wherein the lower expansion cone segments interleave and overlap the upper expansion cone segments and wherein the upper and lower expansion cone segments each approximate an arcuate spherical external surface for plastically deforming and radially expanding the expandable tubular member.

[0084] In another embodiment, an apparatus for radially expanding and plastically deforming an expandable tubular member, is disclosed including a tubular support member, a adjustable expansion cone assembly coupled to the tubular support member, an expandable tubular member coupled to the adjustable expansion cone assembly, means for displacing the adjustable expansion cone assembly relative to the expandable tubular member and means for adjusting the adjustable expansion cone assembly from one effective expansion diameter to another effective expansion diameter.

[0085] In another embodiment the tubular support member includes an upper tubular support member comprising an internal flange and a lower tubular support member comprising an internal flange, wherein the expansion cone includes an upper cam assembly coupled to the upper tubular support member including a tubular base coupled to the upper support member and a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface, a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly and pivotally coupled to the internal flange of the upper tubular support member, a lower cam assembly coupled to the lower tubular support member including a tubular base coupled to the lower tubular support member and a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments, wherein the cams arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower cam assembly and a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment pivotally coupled to the internal flange of the lower tubular support member and mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly; and wherein the apparatus further includes means for releasably coupling the upper tubular support member to the lower tubular support member and means for limiting movement of the upper tubular support member relative to the lower tubular support member.

[0086] In one alternative embodiment the apparatus for radially expanding and plastically deforming an expandable tubular member further includes means for pivoting the upper expansion cone segments and means for pivoting the lower expansion cone segments.

[0087] In one alternative embodiment the apparatus for radially expanding and plastically deforming an expandable tubular member further includes means for pulling the adjustable expansion cone assembly through the expandable tubular member.

[0088] A adjustable expansion cone assembly is disclosed, that includes an upper cam assembly including a tubular base and a plurality of cam arms extending from the tubular base in a downward longitudinal direction, each cam arm defining an inclined surface; a plurality of upper expansion cone segments interleaved with the cam arms of the upper cam assembly, a lower cam assembly including a tubular base and a plurality of cam arms extending from the tubular base in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments, wherein the cam arms of the upper cam assembly are interleaved with and overlap the cam arms of the lower

cam assembly, a plurality of lower expansion cone segments interleaved with cam arms of the lower cam assembly, each lower expansion cone segment mating with the inclined surface of a corresponding one of the cam arms of the upper cam assembly, means for moving the upper cam assembly toward or away from the lower expansion cone segments to adjust the radial position of an external surface of the lower expansion cone segments, and means for moving the lower cam assembly toward or away from the upper expansion cone segments to adjust the radial position of an external surface of the upper expansion cone segments.

[0089] In one embodiment of the adjustable expansion cone assembly, the upper and lower expansion cone segments together approximate an arcuate spherical external surface.

[0090] In one embodiment of the adjustable expansion cone assembly, each upper expansion cone segment comprises an inner portion defining an arcuate cylindrical upper surface and arcuate cylindrical lower surfaces, an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface and an outer portion defining arcuate cylindrical upper and lower surfaces, and wherein each lower expansion cone segment include an inner portion defining an arcuate cylindrical upper surface and arcuate cylindrical lower surfaces, an intermediate portion defining arcuate cylindrical and spherical upper surfaces and an arcuate conical lower surface and an outer portion defining arcuate cylindrical upper and lower surfaces.

[0091] In one embodiment of the adjustable expansion cone assembly, each upper expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion and each lower expansion cone segment is tapered in the longitudinal direction from the intermediate portion to the outer portion.

[0092] An embodiment of an apparatus for radially expanding and plastically deforming an expandable tubular member from an initial inside diameter to a desired diameter of a mono diameter wellbore casing is disclosed, including an upper tubular support member defining a first passage, one or more cup seals coupled to the exterior surface of the upper tubular support member for sealing an interface between the upper tubular support member and the expandable tubular member, an expansion assembly coupled to the upper tubular support member adjustable to one expansion diameter corresponding to the desired diameter of the bell portion of the wellbore casing for forming an expanded bell portion in the expandable tubular member and adjustable to another expansion diameter corresponding to the desired diameter of the mono diameter casing for forming the mono diameter wellbore casing, means for actuating the expandable tubular member to adjust from the one diameter to the other diameter and an actuator for moving the expansion assembly through the expandable tubular member a desired distance with the expansion assembly adjusted to the diameter of the bell portion and for moving the expansion assembly through the expandable tubular member for another distance with the expansion assembly adjusted to the desired diameter of the mono diameter portion of the expandable tubular member.

[0093] According to one alternative embodiment of an apparatus for radially expanding and plastically deforming an expandable tubular member from an initial inside diameter to a desired diameter of a mono diameter wellbore casing, the expansion assembly includes an expansion cone device.

[0094] According to another alternative embodiment of an apparatus for radially expanding and plastically deforming an expandable tubular member from an initial inside diameter to a desired diameter of a mono diameter wellbore casing, the expansion assembly comprises a rotary expansion device.

[0095] According to another alternative embodiment of an apparatus for radially expanding and plastically deforming an expandable tubular member from an initial inside diameter to a desired diameter of a mono diameter wellbore casing, the expansion assembly comprises compliant expansion device.

[0096] According to another alternative embodiment of an apparatus for radially expanding and plastically deforming an expandable tubular member from an initial inside diameter to a desired diameter of a mono diameter well bore casing, the expansion assembly comprises a hydroforming expansion device.

[0097] According to another alternative embodiment of an apparatus for radially expanding and plastically deforming an expandable tubular member from an initial inside diameter to a desired diameter of a mono diameter wellbore casing, the expansion assembly comprises an adjustable expander device that is adjustable to the diameter of the bell portion of the expandable tubular member and wherein the one adjustable expander device is also adjustable to the diameter corresponding to the desired diameter of the mono diameter wellbore casing.

[0098] According to another alternative embodiment of an apparatus for radially expanding and plastically deforming an expandable tubular member from an initial inside diameter to a desired diameter of a mono diameter wellbore casing, the expansion assembly comprises an adjustable expander device that is adjustable to the diameter of the bell portion of the expandable tubular member and wherein the one adjustable expander device is also adjustable to the diameter corresponding to the desired diameter of the mono diameter wellbore casing and wherein the adjustable expander device comprises an adjustable expansion cone device.

[0099] According to another alternative embodiment of an apparatus for radially expanding and plastically deforming an expandable tubular member from an initial inside diameter to a desired diameter of a mono diameter wellbore casing, the expansion assembly comprises an adjustable expander device that is adjustable to the diameter of the bell portion of the expandable tubular member and wherein the one adjustable expander device is

a first portion of the second expandable tubular member below the first portion of the first expandable tubular member, activating the effective expansion diameter of the adjustable expansion assembly to adjust to the second diameter and moving the adjustable expansion assembly through the second expandable tubular member and past the portion overlapping with the first expandable tubular member when the adjustable expansion assembly is adjusted to the third diameter, and to thereby radially expand and plastically deform a second portion of the second expandable tubular member to the same diameter as the expanded remaining portion of the first expandable tubular member.

[0106] In an alternative embodiment the method includes expanding the expandable tubular member using an adjustable expansion cone device

[0107] In an alternative embodiment the method includes expanding the expandable tubular member using an adjustable a rotary expansion device.

[0108] In an alternative embodiment the method includes expanding the expandable tubular member using an adjustable compliant expansion device.

[0109] In an alternative embodiment the method includes expanding the expandable tubular member using an adjustable hydroforming expansion device.

[0110] In an alternative embodiment a method of a casing in a wellbore, includes inserting an expandable tubular member into the wellbore, radially expanding and plastically deforming a lower portion of the expandable tubular member to a first inside diameter; and radially expanding and plastically deforming an upper portion of the expandable tubular member to a second inside diameter; wherein the first inside diameter is larger than the second inside diameter.

[0111] In an alternative embodiment the method of forming a casing in a wellbore, as described in the preceding paragraph, further includes inserting a second expandable tubular member into the expanded expandable tubular member so that a top portion of the second expandable tubular member is overlapped by the expanded lower portion of the expanded expandable tubular member and expanding the top portion of the second expandable tubular member to the second diameter of so that the top portion of the second expandable tubular member is expanded radially outward in the lower portion of the expanded expandable tubular member.

[0112] In an alternative embodiment of the method of forming a casing in a wellbore, expanding the lower and upper portions of the expandable tubular members includes expanding using an expansion cone device.

[0113] In an alternative embodiment of the method of forming a casing in a wellbore, expanding the lower and upper portions of the expandable tubular members includes expanding using a rotary expansion device.

[0114] In an alternative embodiment of the method of forming a casing in a wellbore, expanding the lower and upper portions of the expandable tubular members includes expanding using a compliant expansion device.

[0115] In an alternative embodiment of the method of forming a casing in a wellbore, expanding the lower and upper portions of the expandable tubular members includes expanding using a hydroforming expansion device.

[0116] An alternative embodiment of the method of forming a mono diameter casing in a wellbore includes supporting a first expandable tubular member in the wellbore using a tubular support member and an adjustable expansion cone assembly having a first diameter smaller than the inside diameter of the expandable tubular member, injecting a fluidic material into the tubular support member, sensing the operating pressure of the injected fluidic material within a first interior portion of the tubular support member, displacing the adjustable expansion cone assembly relative to the expandable tubular member and into the wellbore when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the first interior portion of the tubular support member, sensing the operating pressure of the injected fluidic material within a second interior portion of the tubular support member, adjusting the effective expansion diameter of the adjustable expansion cone assembly to a second diameter larger than the inside diameter of the expandable tubular member when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the second interior portion of the tubular support member, moving the adjustable expansion cone assembly having the second diameter a predetermined distance into the expandable tubular member to radially expand and plastically deform a first portion of the expandable tubular member, activating the effective expansion diameter of the adjustable expansion cone assembly to adjust to a second diameter smaller than the first effective expansion diameter and moving the adjustable expansion cone assembly through the expandable tubular member when the adjustable expansion cone assembly is adjusted to the third diameter, to thereby radially expand and plastically deform the remaining portion of the expandable tubular member.

[0117] In an alternative embodiment of the method of forming a mono diameter casing in a wellbore, as described in the preceding paragraph, further includes supporting a second expandable tubular member in the wellbore using a tubular support member and an adjustable expansion cone assembly having a first diameter smaller than the inside diameter of the expandable tubular member, positioning the second expandable tubular member in the expanded first expandable tubular member with the first portion thereof overlapping the second expandable tubular member, injecting a fluidic material into the tubular support member, sensing the operating pressure of the injected fluidic material within a first interior portion of the tubular support member, displacing the adjustable expansion cone assembly relative to the second expandable tubular member and into the wellbore when the sensed operating pressure of the injected fluidic material

also adjustable to the diameter corresponding to the desired diameter of the mono diameter wellbore casing and wherein the adjustable expander device includes an adjustable rotary expansion device.

[0100] According to another alternative embodiment of an apparatus for radially expanding and plastically deforming an expandable tubular member from an initial inside diameter to a desired diameter of a mono diameter wellbore casing, the expansion assembly comprises an adjustable expander device that is adjustable to the diameter of the bell portion of the expandable tubular member and wherein the one adjustable expander device is also adjustable to the diameter corresponding to the desired diameter of the mono diameter wellbore casing and wherein the adjustable expander device includes an adjustable compliant expansion device.

[0101] According to another alternative embodiment of an apparatus for radially expanding and plastically deforming an expandable tubular member from an initial inside diameter to a desired diameter of a mono diameter wellbore casing, the expansion assembly comprises an adjustable expander device that is adjustable to the diameter of the bell portion of the expandable tubular member and wherein the one adjustable expander device is also adjustable to the diameter corresponding to the desired diameter of the mono diameter wellbore casing and wherein the adjustable expander device includes an adjustable hydroforming expansion device.

[0102] According to another alternative embodiment of an apparatus for radially expanding and plastically deforming an expandable tubular member from an initial inside diameter to a desired diameter of a mono diameter wellbore casing, wherein the expansion assembly includes a first adjustable expander device adjustable to the diameter of the bell portion of the expandable tubular member and second adjustable expander device adjustable to the diameter corresponding to the desired diameter of the mono diameter wellbore casing.

[0103] According to another alternative embodiment of an apparatus for radially expanding and plastically deforming an expandable tubular member from an initial inside diameter to a desired diameter of a mono diameter well bore casing, wherein the expansion assembly includes a first adjustable expander device adjustable to the diameter of the bell portion of the expandable tubular member and collapsible after expanding the bell portion and a second expander device having a fixed diameter corresponding to the desired diameter of the mono diameter well bore casing such that collapsing the first adjustable expander device effectively adjusts the effective expansion diameter to the fixed diameter of the second expander device.

[0104] A method of forming a mono diameter casing in a wellbore is disclosed, including supporting a first expandable tubular member in the wellbore using a tubular support member and an adjustable expansion assembly having a first diameter smaller than the inside diameter of the expandable tubular member injecting a fluidic material into the tubular support member, sensing the operating pressure of the injected fluidic material within a first interior portion of the tubular support member, displacing the adjustable expansion assembly relative to the expandable tubular member and into the wellbore when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the first interior portion of the tubular support member, sensing the operating pressure of the injected fluidic material within a second interior portion of the tubular support member, adjusting the effective expansion diameter of the adjustable expansion assembly to a second diameter larger than the inside diameter of the expandable tubular member when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the second interior portion of the tubular support member, moving the adjustable expansion assembly having the second diameter a predetermined distance into the expandable tubular member to radially expand and plastically deform a first portion of the expandable tubular member, activating the effective expansion diameter of the adjustable expansion assembly to adjust to a second diameter smaller than the first effective expansion diameter and moving the adjustable expansion assembly through the expandable tubular member when the adjustable expansion assembly is adjusted to the third diameter, to thereby radially expand and plastically deform the remaining portion of the expandable tubular member.

[0105] In an alternative embodiment, the method of forming a mono diameter wellbore casing as in the paragraph above that further includes supporting a second expandable tubular member in the wellbore using a tubular support member and an adjustable expansion assembly having a first diameter smaller than the inside diameter of the expandable tubular member, positioning the second expandable tubular member in the expanded first expandable tubular member with the first portion thereof overlapping the second expandable tubular member, injecting a fluidic material into the tubular support member, sensing the operating pressure of the injected fluidic material within a first interior portion of the tubular support member, displacing the adjustable expansion assembly relative to the second expandable tubular member and into the well bore when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the first interior portion of the tubular support member, sensing the operating pressure of the injected fluidic material within a second interior portion of the tubular support member, adjusting the effective expansion diameter of the adjustable expansion assembly to the second diameter when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the second interior portion of the tubular support member, moving the adjustable expansion assembly having the second diameter a predetermined distance into the second expandable tubular member to radially expand and plastically deform

exceeds a predetermined level within the first interior portion of the tubular support member, sensing the operating pressure of the injected fluidic material within a second interior portion of the tubular support member, adjusting the effective expansion diameter of the adjustable expansion cone assembly to the second diameter when the sensed operating pressure of the injected fluidic material exceeds a predetermined level within the second interior portion of the tubular support member, moving the adjustable expansion cone assembly having the second diameter a predetermined distance into the second expandable tubular member to radially expand and plastically deform a first portion of the second expandable tubular member below the first portion of the first expandable tubular member, activating the effective expansion diameter of the adjustable expansion cone assembly to adjust to the second diameter and moving the adjustable expansion cone assembly through the second expandable tubular member and past the portion overlapping with the first expandable tubular member when the adjustable expansion cone assembly is adjusted to the third diameter, and to thereby radially expand and plastically deform a second portion of the second expandable tubular member to the same diameter as the expanded remaining portion of the first expandable tubular member.

Claims

1. An apparatus for radially expanding and plastically deforming an expandable tubular member (14), comprising:

    a support member (30);
    an adjustable expansion cone assembly (16) coupled to the support member (30);
    an expandable tubular member (14) coupled to the adjustable expansion cone assembly (16), **characterised by:**

        means for displacing the adjustable expansion cone assembly (16) relative to the expandable tubular member (14) and the support member (30); and
        means for adjusting the adjustable expansion cone assembly (16) from one effective expansion diameter to another effective expansion diameter.

2. The apparatus of claim 1, wherein the support member (30) comprises an upper support member (94) comprising an internal flange (94d) and a lower support member (100) comprising an internal flange (100d); and wherein the expansion cone (16) comprises:

    an upper cam assembly (90) coupled to the upper support member (94) comprising:

        a tubular base (40a) coupled to the upper support member (94); and
        a plurality of cam arms (40c) extending from the tubular base (90a) in a downward longitudinal direction, each cam arm defining an inclined surface;

    a plurality of upper expansion cone segments (96) interleaved with the cam arms (90c) of the upper cam assembly (90) and pivotally coupled to the internal flange (94d) of the upper support member (94);
    a lower cam assembly coupled to the lower support member (100) comprising:

        a tubular base (92a) coupled to the lower support member (100); and
        a plurality of cam arms (92c) extending from the tubular base (92a) in an upward longitudinal direction, each cam arm defining an inclined surface that mates with the inclined surface of a corresponding one of the upper expansion cone segments (96);

    wherein the cams arms (90c) of the upper cam assembly (90) are interleaved with and overlap the cam arms (92c) of the lower cam assembly (92); and
    a plurality of lower expansion cone segments (98) interleaved with cam arms (92c) of the lower cam assembly (92), each lower expansion cone segment (98) pivotally coupled to the internal flange (100d) of the lower support member (100) and mating with the inclined surface of a corresponding one of the cam arms (90c) of the upper cam assembly (90); and wherein the apparatus further comprises:

        means for releasably coupling the upper support member (94) to the lower support member (100); and
        means for limiting movement of the upper support member (94) relative to the lower support member (100).

3. The apparatus of claim 1, further comprising:

    means for pivoting the upper expansion cone segments (96); and
    means for pivoting the lower expansion cone segments (98).

4. The apparatus of claim 1, further comprising:

    means for pulling the adjustable expansion cone assembly (16) through the expandable tubular member (14).

5. A method of forming a casing in a wellbore (12), comprising:

positioning an expansion device within an expandable tubular member (14),

characterised by:

positioning the expansion device and the expandable tubular member (14) into the wellbore (12);
lowering the expansion device out of an end of the expandable tubular member (14) within the wellbore (12);
radially expanding and plastically deforming a lower portion (22a) of the expandable tubular member (14) to a first inside diameter (ID_2) using the expansion device; and
radially expanding and plastically deforming an upper portion (28a) of the expandable tubular member (14) to a second inside diameter (ID_1) using the expansion device, wherein the first inside diameter is larger than the second inside diameter.

6. The method of claim 5 further comprising:

inserting a second expandable tubular member (18b), into the expanded expandable tubular member (18a) so that a top portion (28b) of the second expandable tubular member (18b) is overlapped by the expanded lower portion (22a) of the expanded expandable tubular member (18a); and
expanding the top portion (28b) of the second expandable tubular member (18b) to the second diameter (ID_1) so that the top portion (28b) of the second expandable tubular member (18b) is expanded radially outward in the expanded lower portion (22a) of the expanded expandable tubular member (18a).

7. The method of claim 5, wherein the expanding the lower and upper portions (22, 28) of the expandable tubular members (18a, 18b) comprises expanding using an expansion cone device (16).

8. The method of claim 5, wherein the expanding the lower and upper portions (22, 28) of the expandable tubular members (18a, 18b) comprises expanding using a rotary expansion device.

9. The method of claim 5, wherein the expanding the lower and upper portions (22, 28) of the expandable tubular members (18a, 18b) comprises expanding using a compliant expansion device.

10. The method of claim 5, wherein the expanding the lower and upper portions (22, 28) of the expandable tubular members (18a, 18b) comprises expanding using a hydroforming expansion device (24).

Patentansprüche

1. Vorrichtung zum radialen Aufweiten und plastischen Verformen eines ausdehnbaren rohrförmigen Teils (14), umfassend:

ein Trageteil (30);
eine einstellbare Ausdehnkonus-Baugruppe (16), die mit dem Trageteil (30) verbunden ist;
ein ausdehnbares rohrförmiges Teil (14), das mit der einstellbaren Ausdehnkonus-Baugruppe (16) verbunden ist, **gekennzeichnet durch:**

Mittel zum Verschieben der einstellbaren Ausdehnkonus-Baugruppe (16) gegen das ausdehnbare rohrförmige Teil (14) und das Trageteil (30); und
Mittel zum Einstellen der einstellbaren Ausdehnkonus-Baugruppe (16) von einem effektiven Ausdehnungsdurchmesser auf einen anderen effektiven Ausdehnungsdurchmesser.

2. Vorrichtung nach Anspruch 1, wobei das Trageteil (30) ein oberes Trageteil (94) umfasst, das einen inneren Flansch (94d) enthält, und ein unteres Trageteil (100), das einen inneren Flansch (100d) enthält; und wobei der Ausdehnkonus (16) umfasst:

eine obere Nockenbaugruppe (90), die mit dem oberen Trageteil (94) verbunden ist, umfassend:

eine rohrförmige Basis (40a), die mit dem oberen Trageteil (94) verbunden ist; und
eine Anzahl Nockenarme (40c), die sich von der rohrförmigen Basis (90a) in einer Längsrichtung nach unten erstrecken, wobei jeder Nockenarm eine geneigte Oberfläche bestimmt;

eine Anzahl oberer Ausdehnkonussegmente (96), die mit den Nockenarmen (90c) der oberen Nockenbaugruppe (90) verschachtelt sind und schwenkbar an den inneren Flansch (94d) des oberen Trageteils (94) gekoppelt sind;
eine untere Nockenbaugruppe, die mit dem unteren Trageteil (100) verbunden ist, umfassend:

eine rohrförmige Basis (92a), die mit dem unteren Trageteil (100) gekoppelt ist; und
eine Anzahl Nockenarme (92c), die sich von der rohrförmigen Basis (92a) in einer Längsrichtung nach oben erstrecken, wo-

bei jeder Nockenarm eine geneigte Oberfläche bestimmt, die mit der geneigten Oberfläche eines zugeordneten oberen Ausdehnkonussegments (96) zusammenpasst,

wobei die Nockenarme (90c) der oberen Nockenbaugruppe (90) mit den Nockenarmen (92c) der unteren Nockenbaugruppe (92) verschachtelt sind und sie überlappen; und
eine Anzahl unterer Ausdehnkonussegmente (98), die mit den Nockenarmen (92c) der unteren Nockenbaugruppe (92) verschachtelt sind, wobei jedes untere Ausdehnkonussegment (98) schwenkbar mit dem inneren Flansch (100d) des unteren Trageteils (100) verbunden ist und mit der geneigten Oberfläche eines zugeordneten Nockenarms (90c) der oberen Nockenbaugruppe (90) zusammenpasst; und worin die Vorrichtung ferner umfasst:

Mittel zum lösbaren Verbinden des oberen Trageteils (94) und des unteren Trageteils (100); und
Mittel zum Begrenzen der Bewegung des oberen Trageteils (94) gegen das untere Trageteil (100).

3. Vorrichtung nach Anspruch 1, zudem umfassend:

Mittel zum Schwenken der oberen Ausdehnkonussegmente (96); und
Mittel zum Schwenken der unteren Ausdehnkonussegmente (98).

4. Vorrichtung nach Anspruch 1, zudem umfassend:

Mittel zum Ziehen der einstellbaren Ausdehnkonus-Baugruppe (16) durch das ausdehnbare rohrförmige Teil (14).

5. Verfahren zum Ausbilden eines Futterrohrs in einem Bohrloch (12), umfassend:

das Anordnen einer Ausdehnvorrichtung innerhalb eines ausdehnbaren rohrförmigen Teils (14), **gekennzeichnet durch**:

das Anordnen der Ausdehnvorrichtung und des ausdehnbaren rohrförmigen Teils (14) in dem Bohrloch (12);
das Absenken der Ausdehnvorrichtung aus einem Ende des ausdehnbaren rohrförmigen Teils (14) hinaus in das Bohrloch (12);
das radiale Ausdehnen und plastische Verformen eines unteren Abschnitts (22a) des ausdehnbaren rohrförmigen Teils (14) auf einen ersten Innendurchmesser (ID_2) mit Hilfe der Ausdehnvorrichtung; und
das radiale Ausdehnen und plastische Verformen eines oberen Abschnitts (28a) des ausdehnbaren rohrförmigen Teils (14) auf einen zweiten Innendurchmesser (ID_1) mit Hilfe der Ausdehnvorrichtung, wobei der erste Innendurchmesser größer ist als der zweite Innendurchmesser.

6. Verfahren nach Anspruch 5, zudem umfassend:

das Einsetzen eines zweiten ausdehnbaren rohrförmigen Teils (18b) in das aufgeweitete ausdehnbare rohrförmige Teil (18a), so dass ein oberer Abschnitt (28b) des zweiten ausdehnbaren rohrförmigen Teils (18b) vom ausgeweiteten unteren Abschnitt (22a) des aufgeweiteten ausdehnbaren rohrförmigen Teils (18a) überlappt wird; und
das Ausdehnen des oberen Abschnitts (28b) des zweiten ausdehnbaren rohrförmigen Teils (18b) auf den zweiten Durchmesser (ID_1), so dass der obere Abschnitt (28b) des zweiten ausdehnbaren rohrförmigen Teils (18b) radial nach außen in den ausgeweiteten unteren Abschnitt (22a) des aufgeweiteten ausdehnbaren rohrförmigen Teils (18a) ausgedehnt wird.

7. Verfahren nach Anspruch 5, wobei das Ausdehnen der unteren und oberen Abschnitte (22, 28) der ausdehnbaren rohrförmigen Teile (18a, 18b) das Ausdehnen mit Hilfe einer Ausdehnkonusvorrichtung (16) umfasst.

8. Verfahren nach Anspruch 5, worin das Ausdehnen der unteren und oberen Abschnitte (22, 28) der ausdehnbaren rohrförmigen Teile (18a, 18b) das Ausdehnen mit Hilfe einer drehbaren Ausdehnvorrichtung umfasst.

9. Verfahren nach Anspruch 5, worin das Ausdehnen der unteren und oberen Abschnitte (22, 28) der ausdehnbaren rohrförmigen Teile (18a, 18b) das Ausdehnen mit Hilfe einer nachgiebigen Ausdehnvorrichtung umfasst.

10. Verfahren nach Anspruch 5, worin das Ausdehnen der unteren und oberen Abschnitte (22, 28) der ausdehnbaren rohrförmigen Teile (18a, 18b) das Ausdehnen mit Hilfe einer Hydroforming-Ausdehnvorrichtung (24) umfasst.

Revendications

1. Dispositif pour développer radialement et déformer plastiquement un élément tubulaire extensible (14), comprenant :

un élément de support (30) ;
un ensemble de cône d'expansion réglable (16) couplé à l'élément de support (30) ;
un élément tubulaire extensible (14) couplé à l'ensemble de cône d'expansion réglable (16),
caractérisé par :

un moyen pour déplacer l'ensemble de cône d'expansion réglable (16) par rapport à l'élément tubulaire extensible (14) et à l'élément de support (30) ; et
un moyen pour régler l'ensemble de cône d'expansion réglable (16) d'un diamètre d'expansion effectif à un autre diamètre d'expansion effectif.

2. Dispositif selon la revendication 1, dans lequel l'élément de support (30) comprend un élément de support supérieur (94) comprenant une bride interne (94d) et un élément de support inférieur (100) comprenant une bride interne (100d), et dans lequel le cône d'expansion (16) comprend :

un ensemble de came supérieur (90) couplé à l'élément de support supérieur (94) comprenant :

une base tubulaire (40a) couplée à l'élément de support supérieur (94) ; et
une pluralité de bras de came (40c) s'étendant depuis la base tubulaire (90a) dans une direction longitudinale orientée vers le bas, chaque bras de came définissant une surface inclinée ;

une pluralité de segments de cône d'expansion supérieurs (96) entrelacés avec les bras de came (90c) de l'ensemble de came supérieur (90) et couplés à pivotement à la bride interne (94d) de l'élément de support supérieur (94) ;
un ensemble de came inférieur couplé à l'élément de support inférieur (100) comprenant :

une base tubulaire (92a) couplée à l'élément de support inférieur (100) ; et
une pluralité de bras de came (92c) s'étendant depuis la base tubulaire (92a) dans une direction longitudinale orientée vers le haut, chaque bras de came définissant une surface inclinée qui s'accouple avec la surface inclinée d'un segment correspondant parmi les segments de cône d'expansion supérieurs (96) ;

dans lequel les bras de came (90c) de l'ensemble de came supérieur (90) sont entrelacés avec et chevauchent les bras de came (92c) de l'ensemble de came inférieur (92) ; et
une pluralité de segments de cône d'expansion inférieurs (98) entrelacés avec des bras de came (92c) de l'ensemble de came inférieur (92), chaque segment de cône d'expansion inférieur (98) étant couplé à pivotement à la bride interne (100d) de l'élément de support inférieur (100) et s'accouplant avec la surface inclinée d'un bras de came (90c) correspondant de l'ensemble de came supérieur (90) ; et dans lequel le dispositif comprend en outre :

un moyen pour coupler de manière libérable l'élément de support supérieur (94) à l'élément de support inférieur (100) ; et
un moyen pour limiter le mouvement de l'élément de support supérieur (94) par rapport à l'élément de support inférieur (100).

3. Dispositif selon la revendication 1, comprenant en outre :

un moyen pour faire pivoter les segments de cône d'expansion supérieurs (96) ; et
un moyen pour faire pivoter les segments de cône d'expansion inférieurs (98).

4. Dispositif selon la revendication 1, comprenant en outre un moyen pour tirer l'ensemble de cône d'expansion réglable (16) à travers l'élément tubulaire extensible (14).

5. Procédé de formation d'un tubage dans un puits de forage (12), comprenant les opérations consistant à :

positionner un dispositif d'expansion à l'intérieur d'un élément tubulaire extensible (14),

caractérisé par les opérations consistant à :

positionner le dispositif d'expansion et l'élément tubulaire extensible (14) dans le puits de forage (12) ;
abaisser le dispositif d'expansion dans le puits de forage (12) en le faisant sortir par une extrémité de l'élément tubulaire extensible (14) ;
développer radialement et déformer plastiquement une partie inférieure (22a) de l'élément tubulaire extensible (14) jusqu'à un premier diamètre intérieur (ID_2) en utilisant le dispositif d'expansion ; et
développer radialement et déformer plastiquement une partie supérieure (28a) de l'élément tubulaire extensible (14) jusqu'à un deuxième diamètre intérieur (ID_1) en utilisant le dispositif d'expansion, le premier diamètre intérieur étant plus grand que le deuxième diamètre intérieur.

6. Procédé selon la revendication 5, comprenant en outre :

l'insertion d'un deuxième élément tubulaire extensible (18b) dans l'élément tubulaire extensible étendu (18a) de telle manière qu'une partie supérieure (28b) du deuxième élément tubulaire extensible (18b) est recouverte par la partie inférieure étendue (22a) de l'élément tubulaire extensible étendu (18a) ; et
le développement de la partie supérieure (28b) du deuxième élément tubulaire extensible (18b) jusqu'au deuxième diamètre (ID_1) de telle manière que la partie supérieure (28b) du deuxième élément tubulaire extensible (18b) est étendue radialement vers l'extérieur dans la partie inférieure étendue (22a) de l'élément tubulaire extensible étendu (18a).

7. Procédé selon la revendication 5, dans lequel le développement des parties inférieure et supérieure (22, 28) des éléments tubulaires extensibles (18a, 18b) comprend le fait de développer en employant un dispositif de cône d'expansion (16).

8. Procédé selon la revendication 5, dans lequel le développement des parties inférieure et supérieure (22, 28) des éléments tubulaires extensibles (18a, 18b) comprend le fait de développer en employant un dispositif d'expansion rotatif.

9. Procédé selon la revendication 5, dans lequel le développement des parties inférieure et supérieure (22, 28) des éléments tubulaires extensibles (18a, 18b) comprend le fait de développer en employant un dispositif d'expansion souple.

10. Procédé selon la revendication 5, dans lequel le développement des parties inférieure et supérieure (22, 28) des éléments tubulaires extensibles (18a, 18b) comprend le fait de développer en employant un dispositif d'expansion par hydroformage (24).

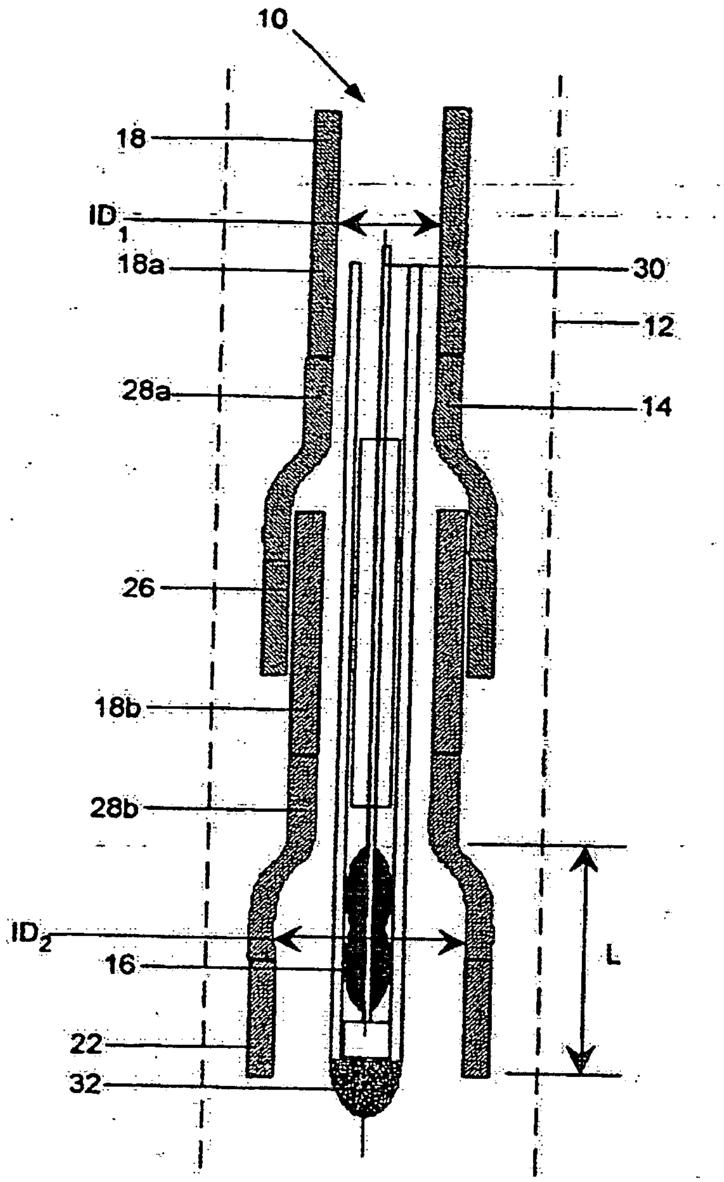

Fig. 1

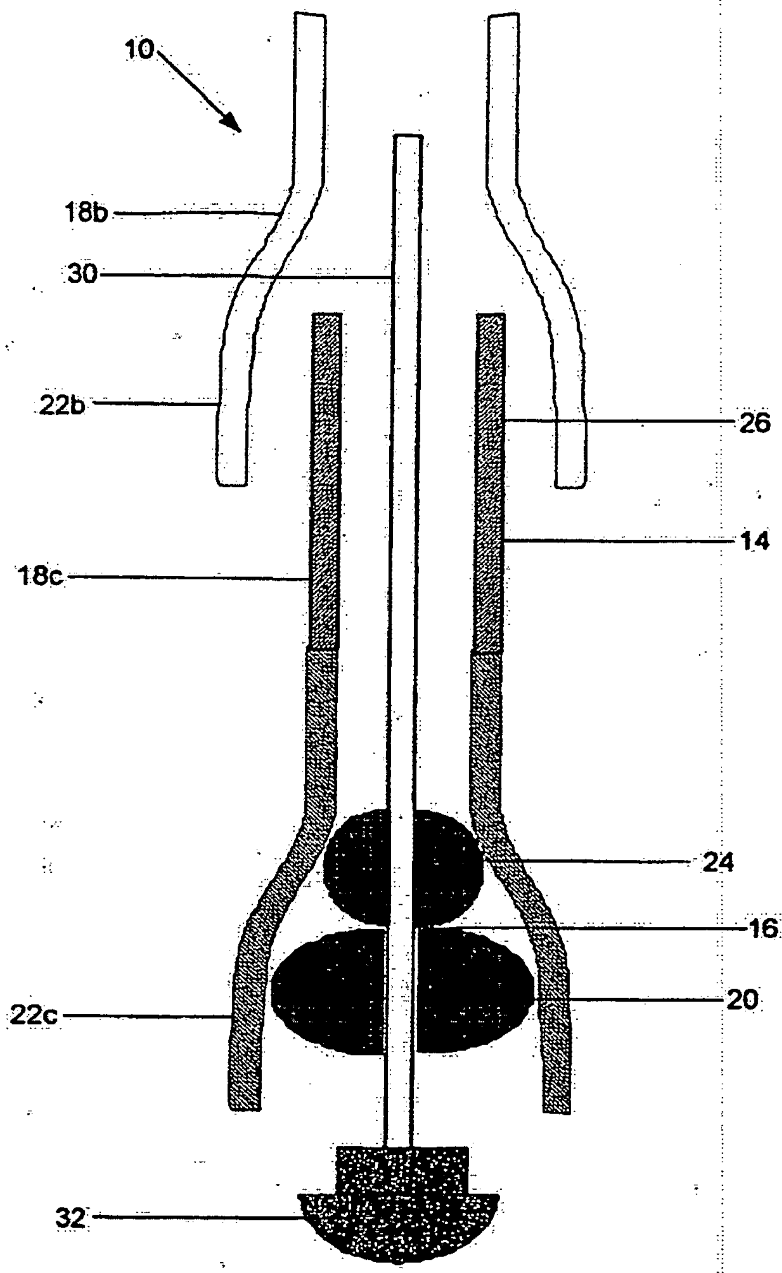

Fig. 2

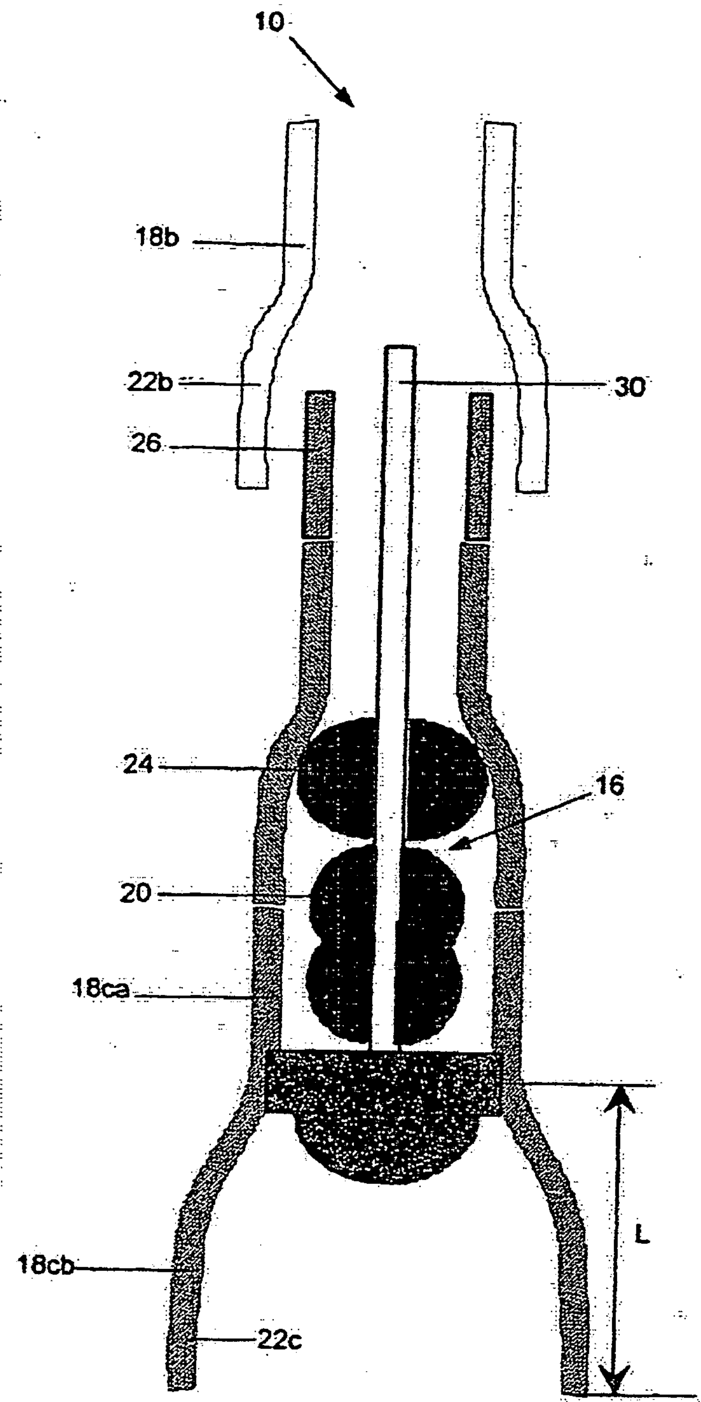

Fig. 3

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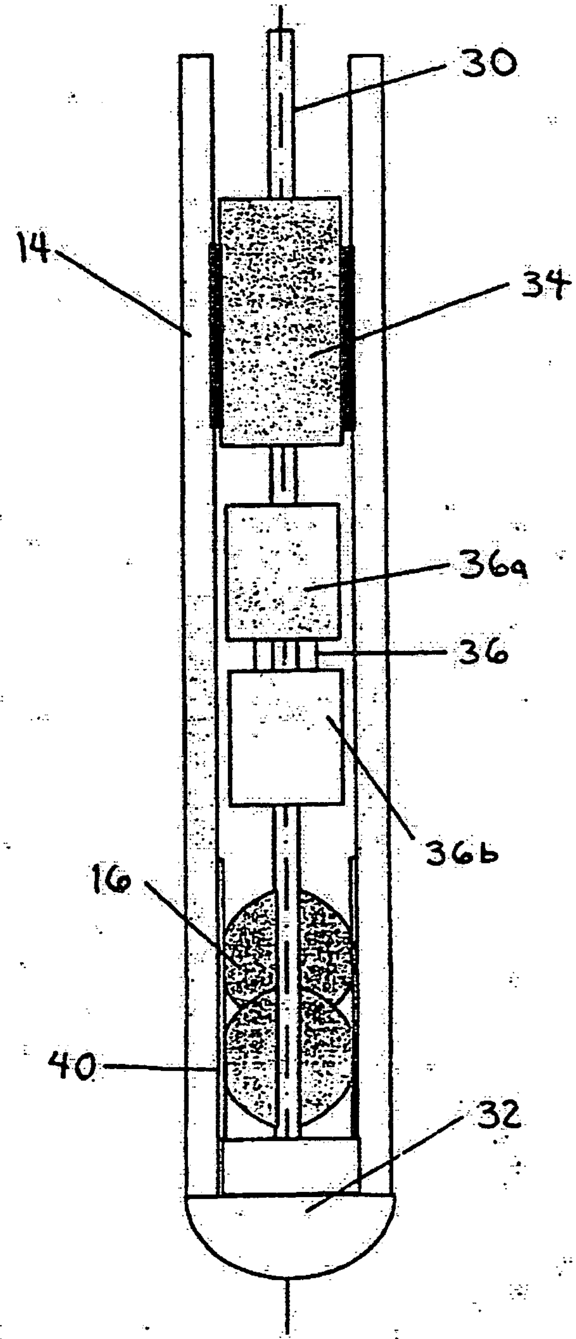


FIG. 4

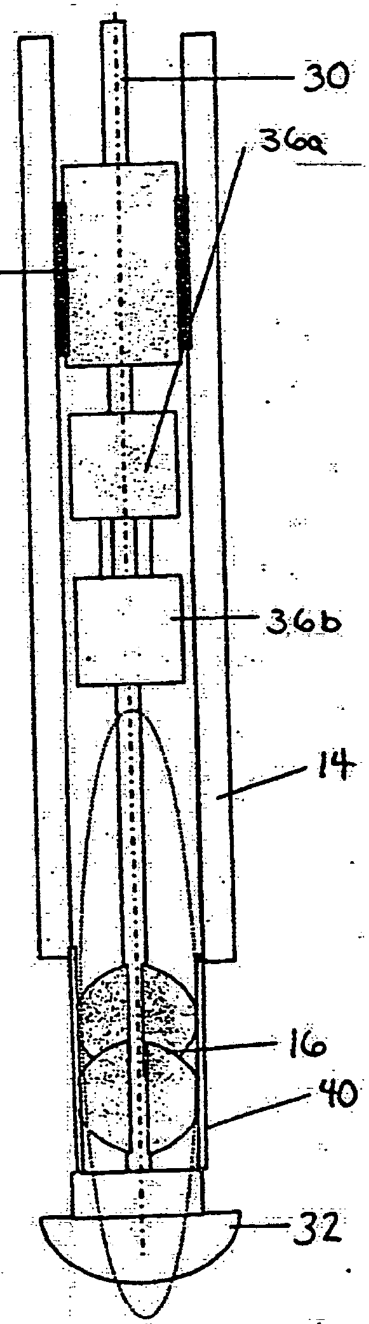


FIG.5

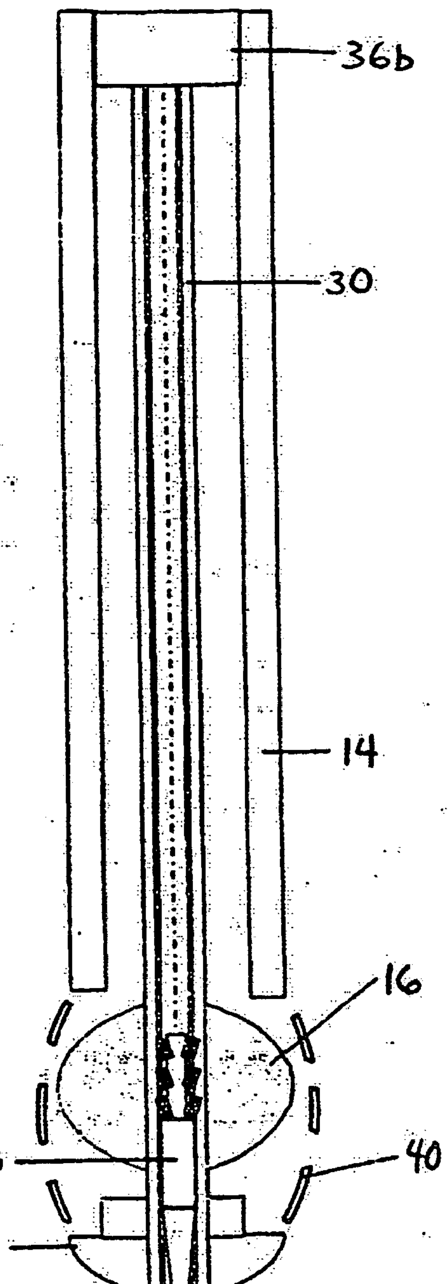


FIG.6

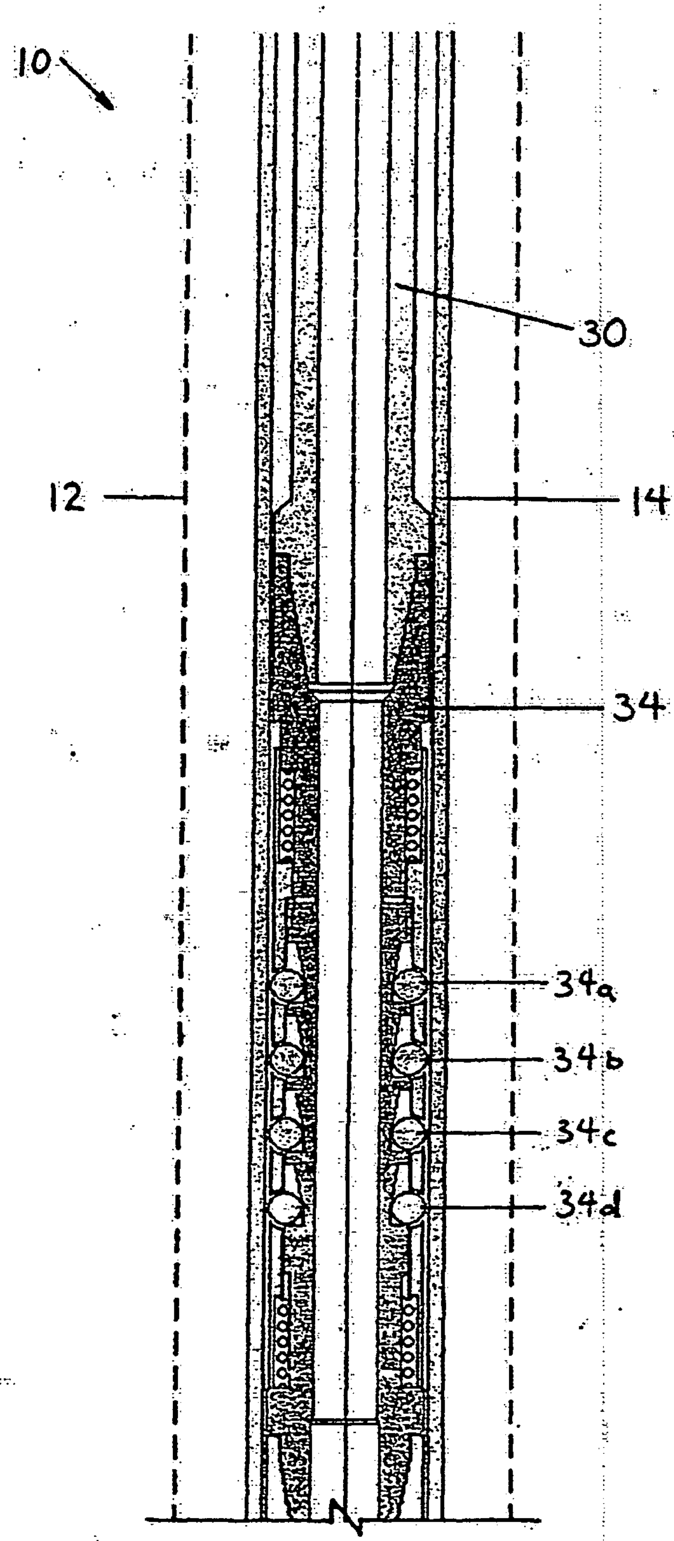


Fig. 7a

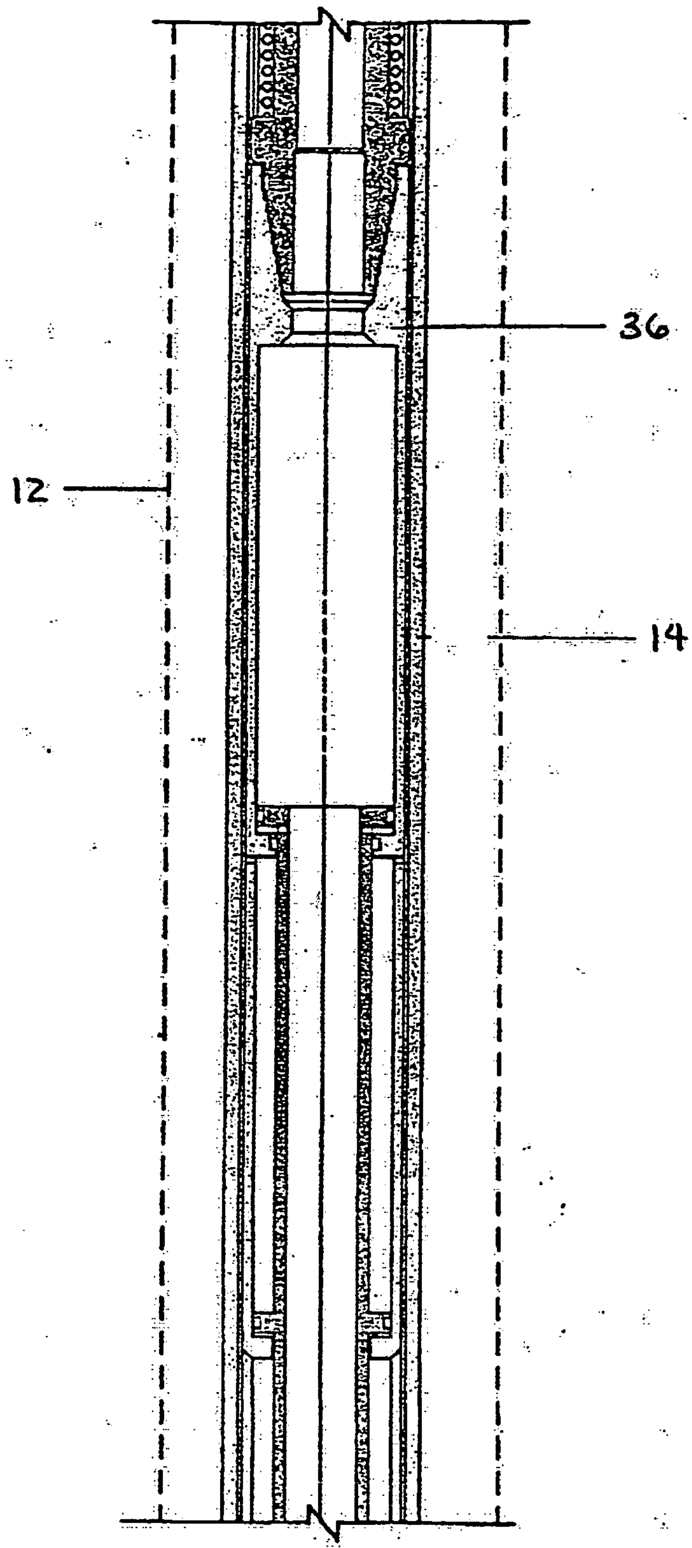


Fig. 7b

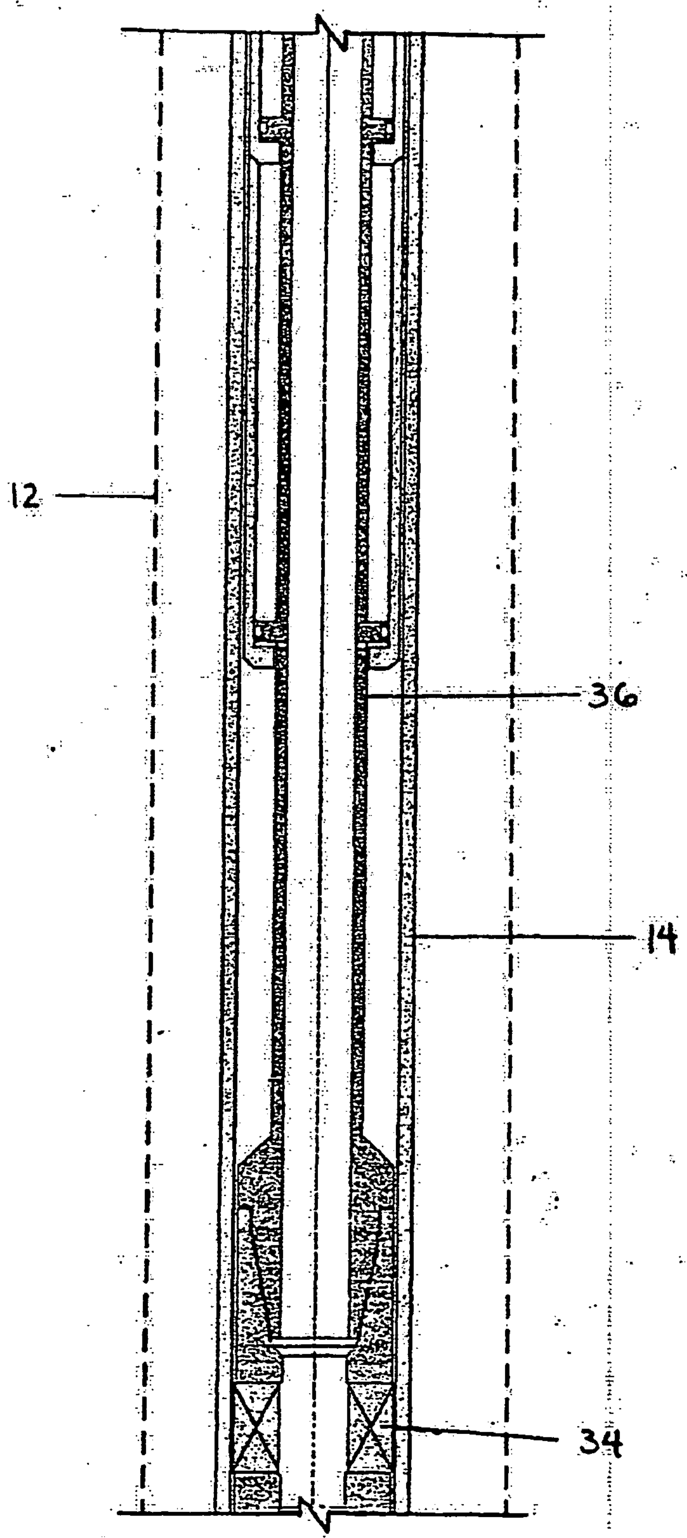


Fig 7c

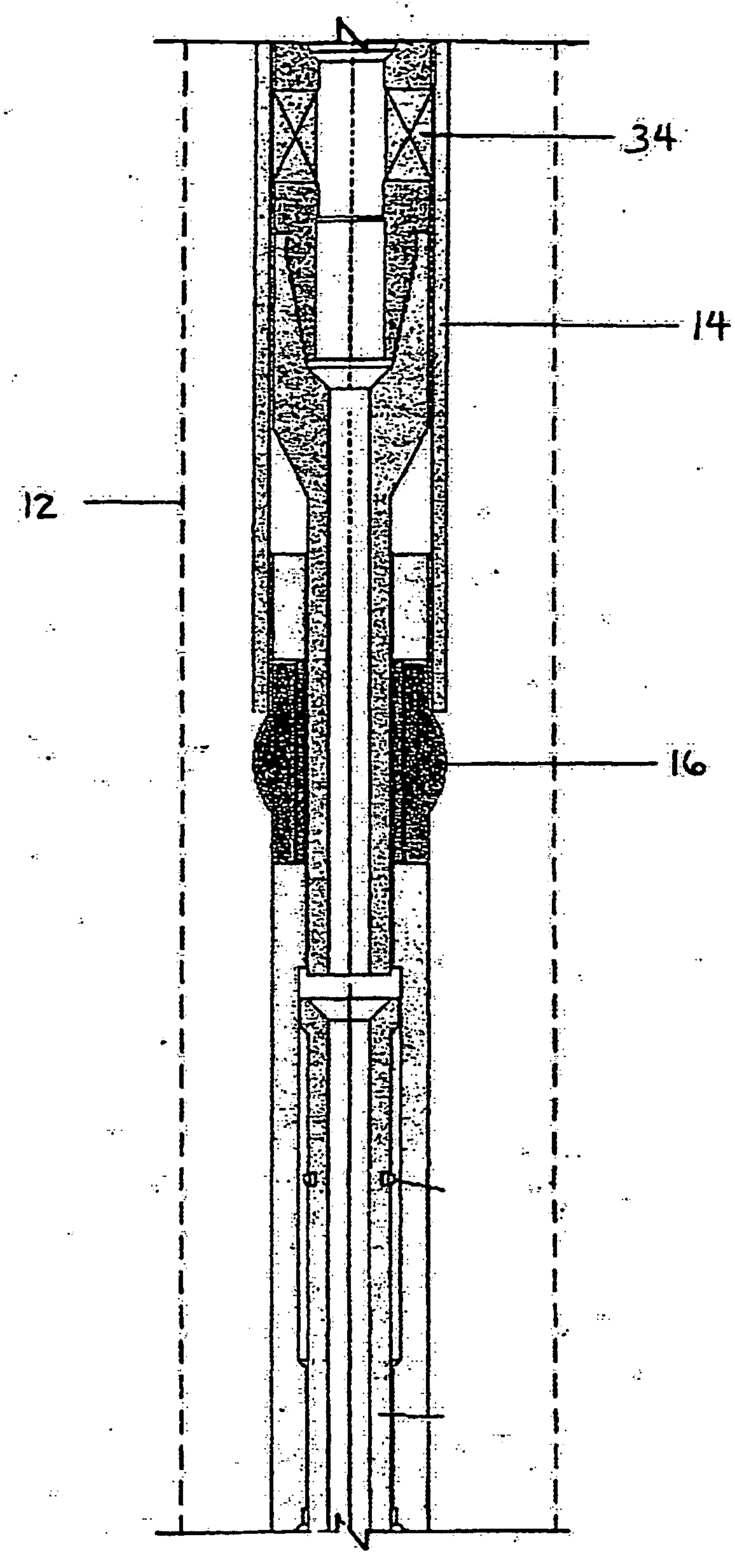


Fig. 7d

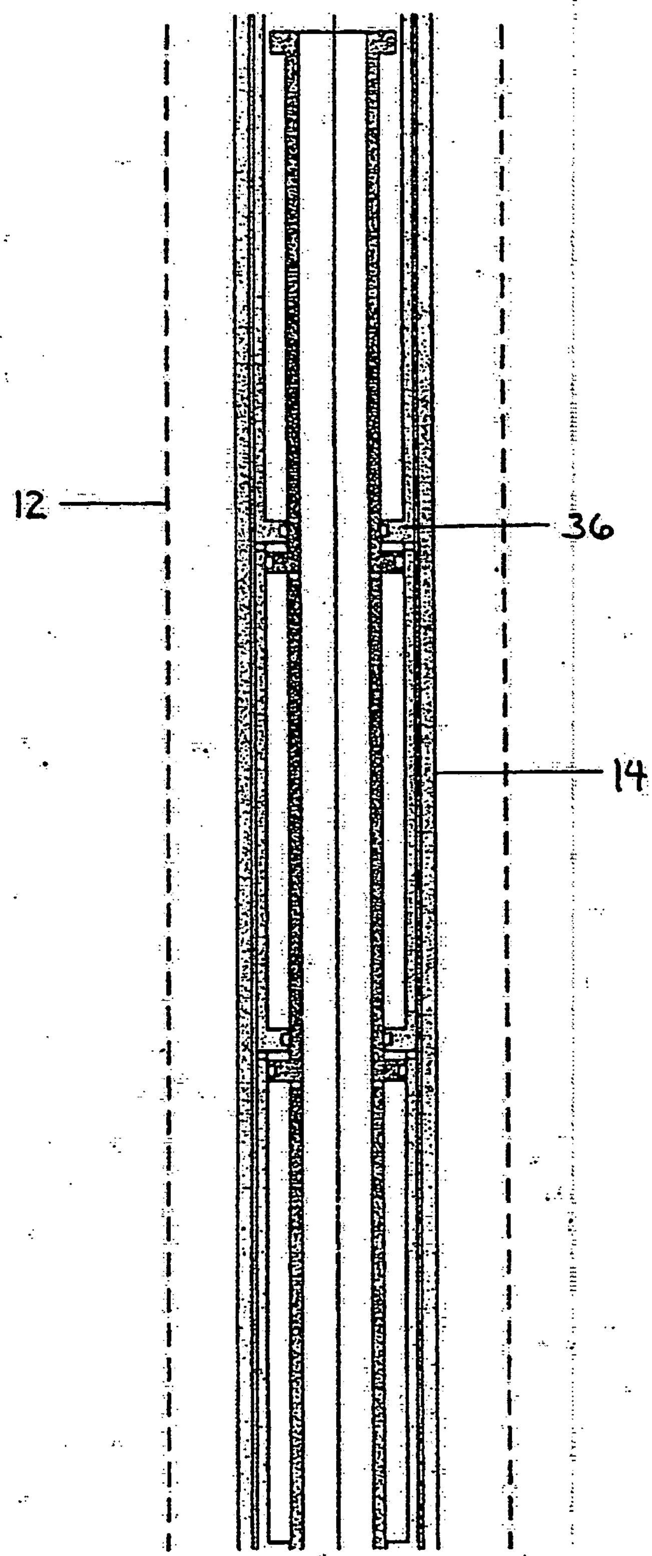


Fig. 8b

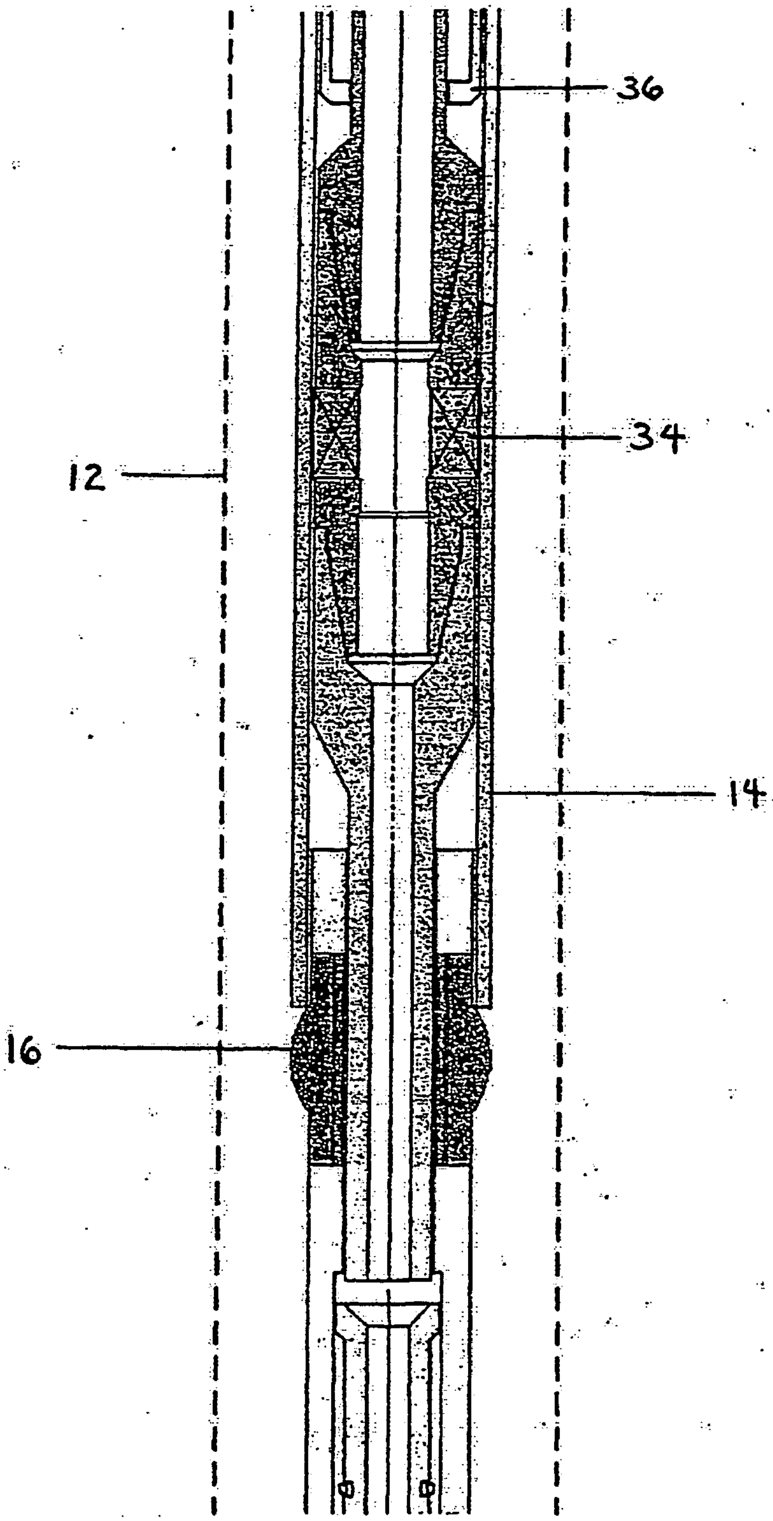


Fig. 8c

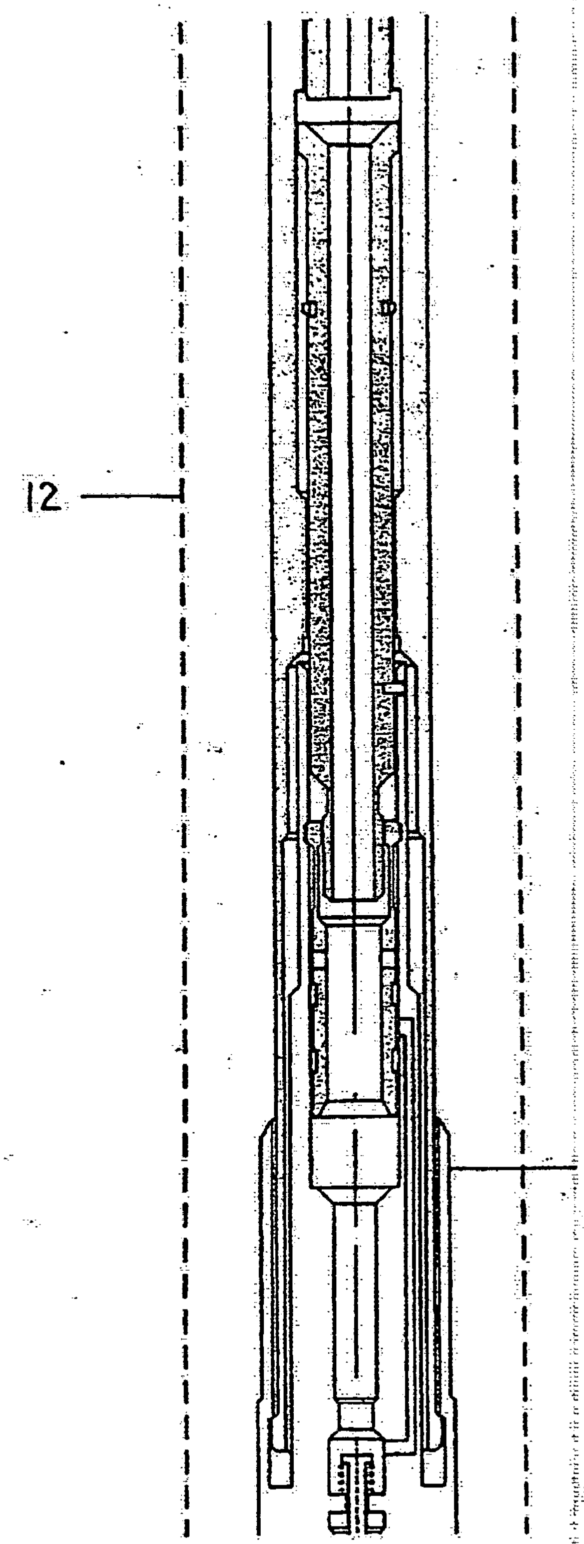


Fig. 8d

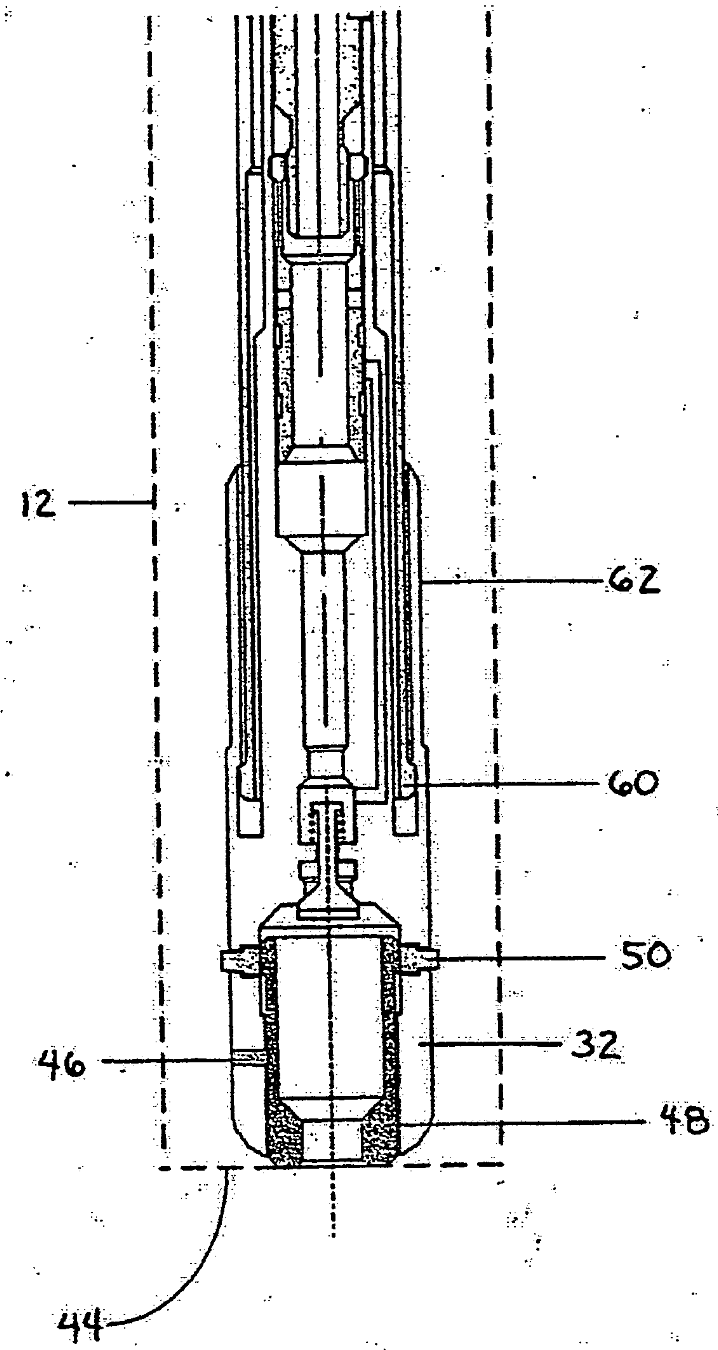


Fig. 8e

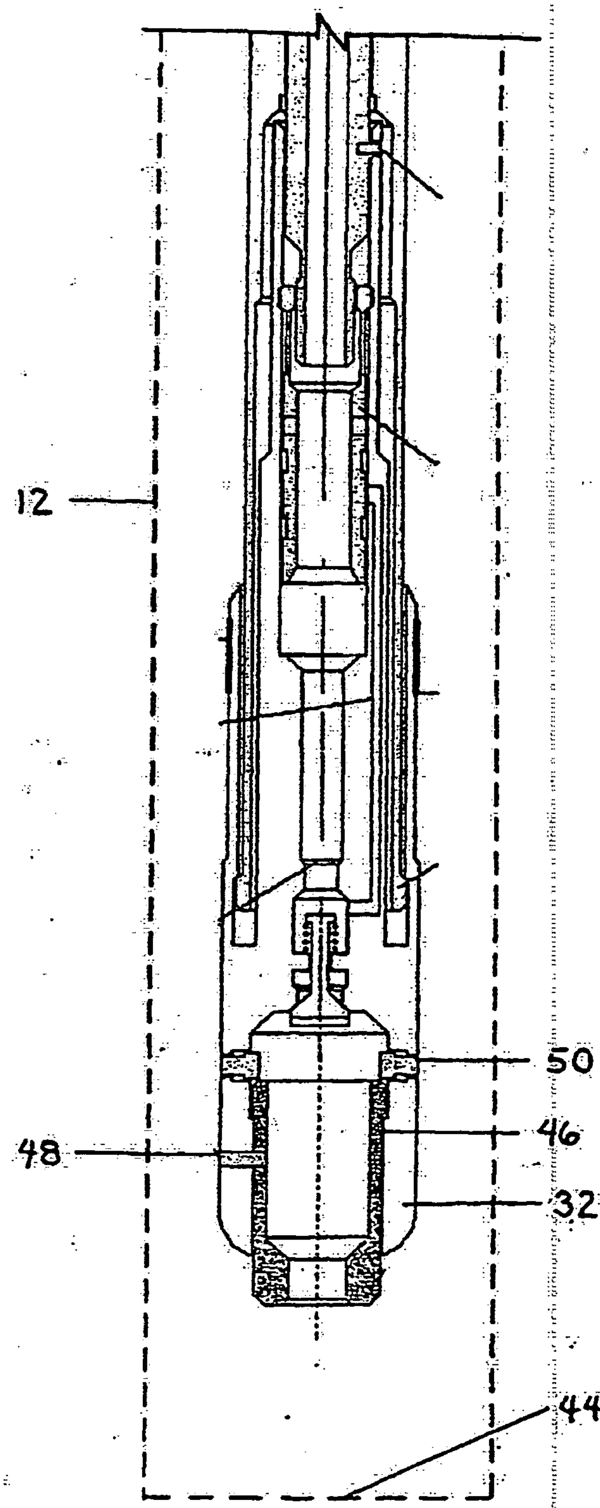


Fig. 7e

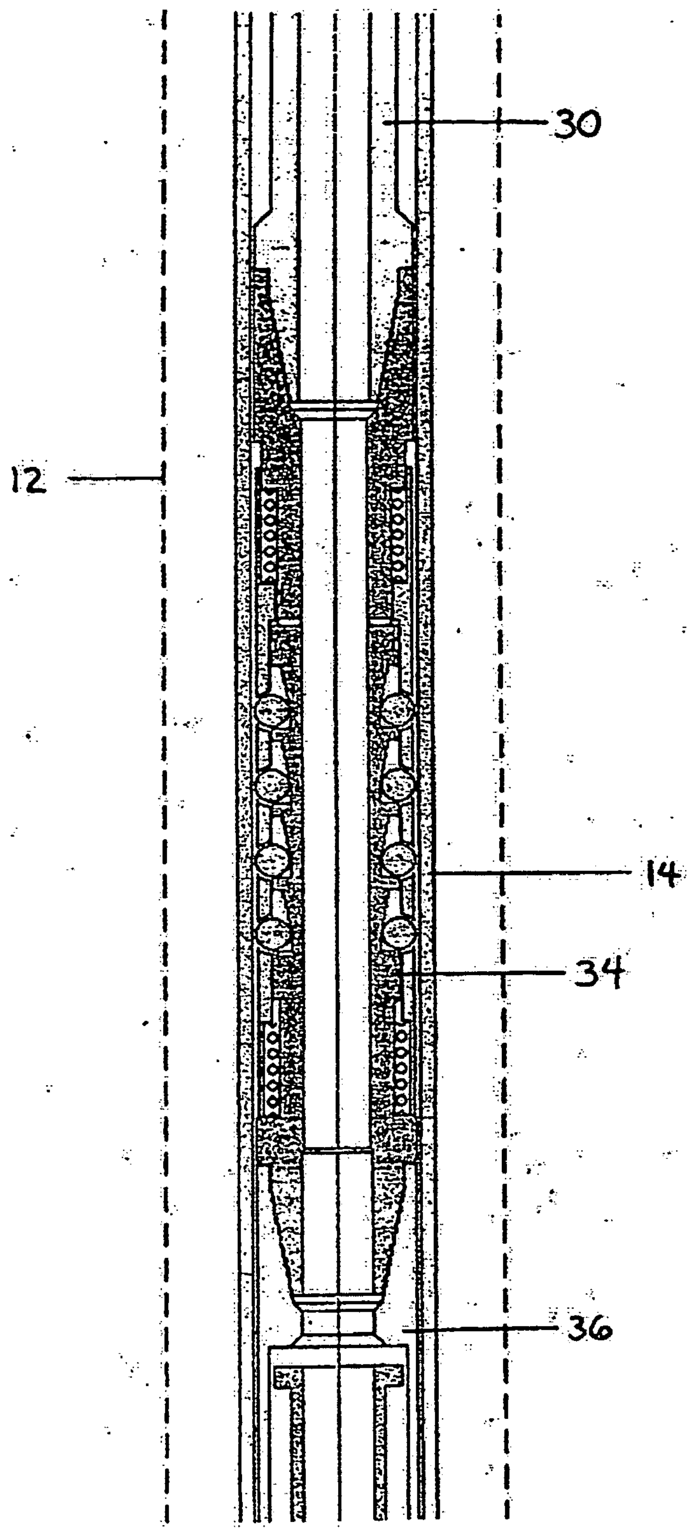


Fig. 8a

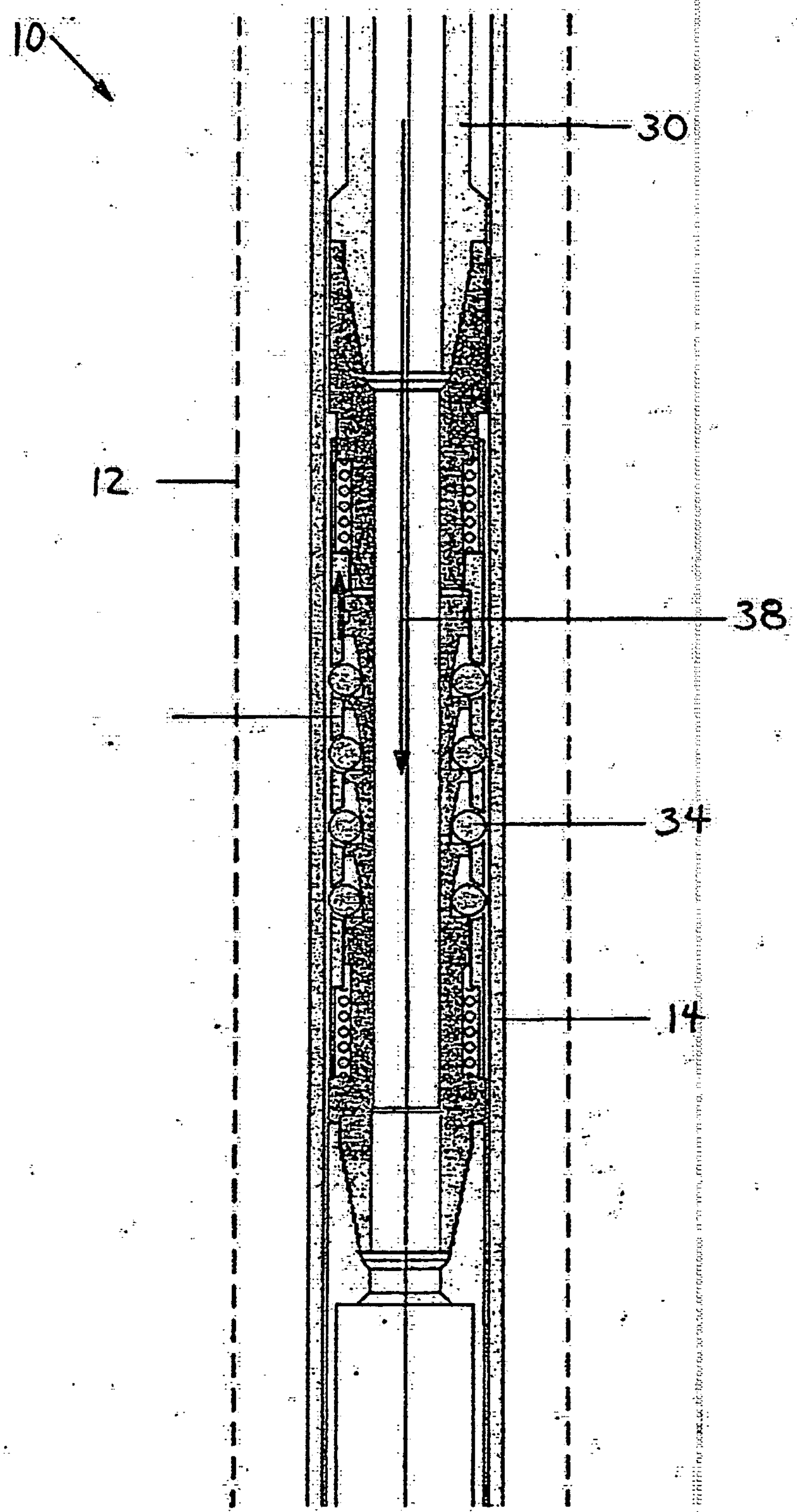


Fig. 9a

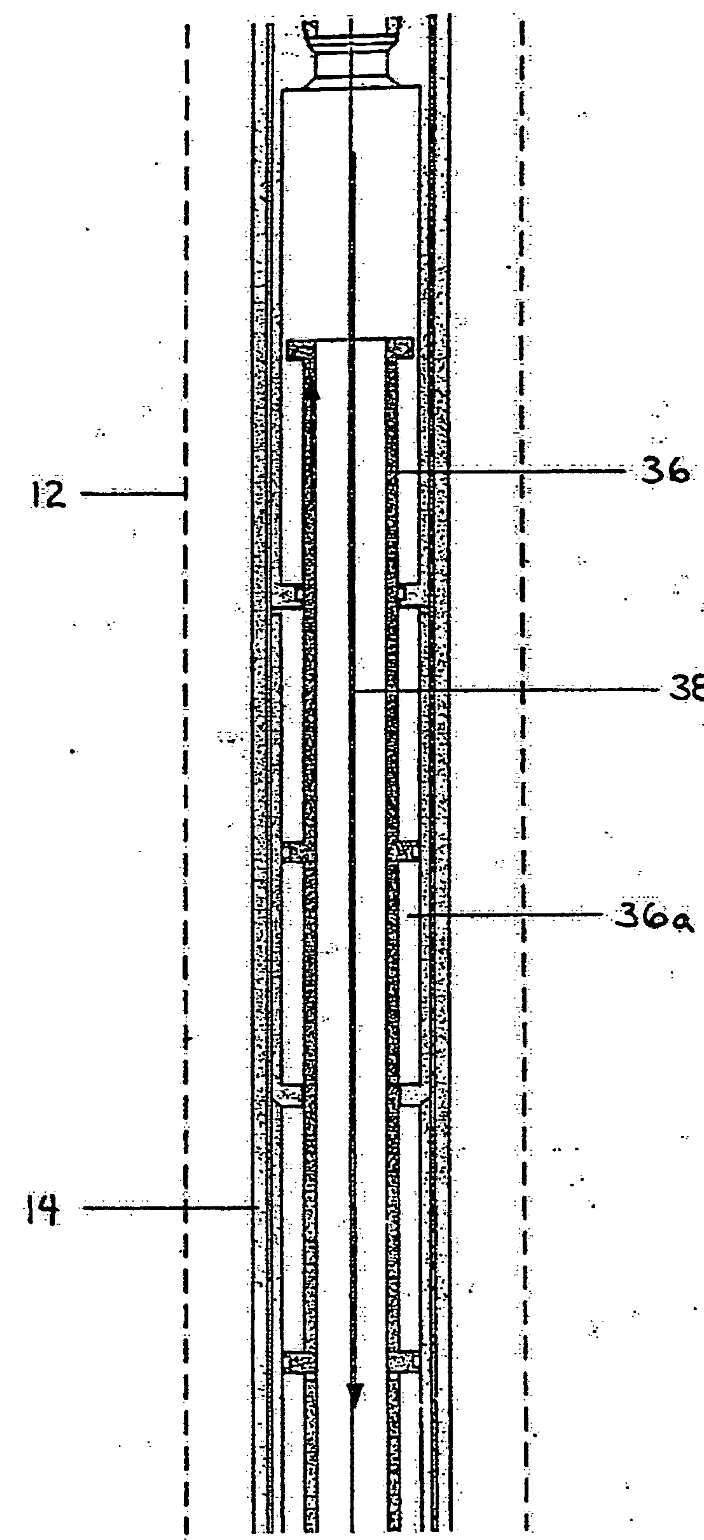


Fig. 9b

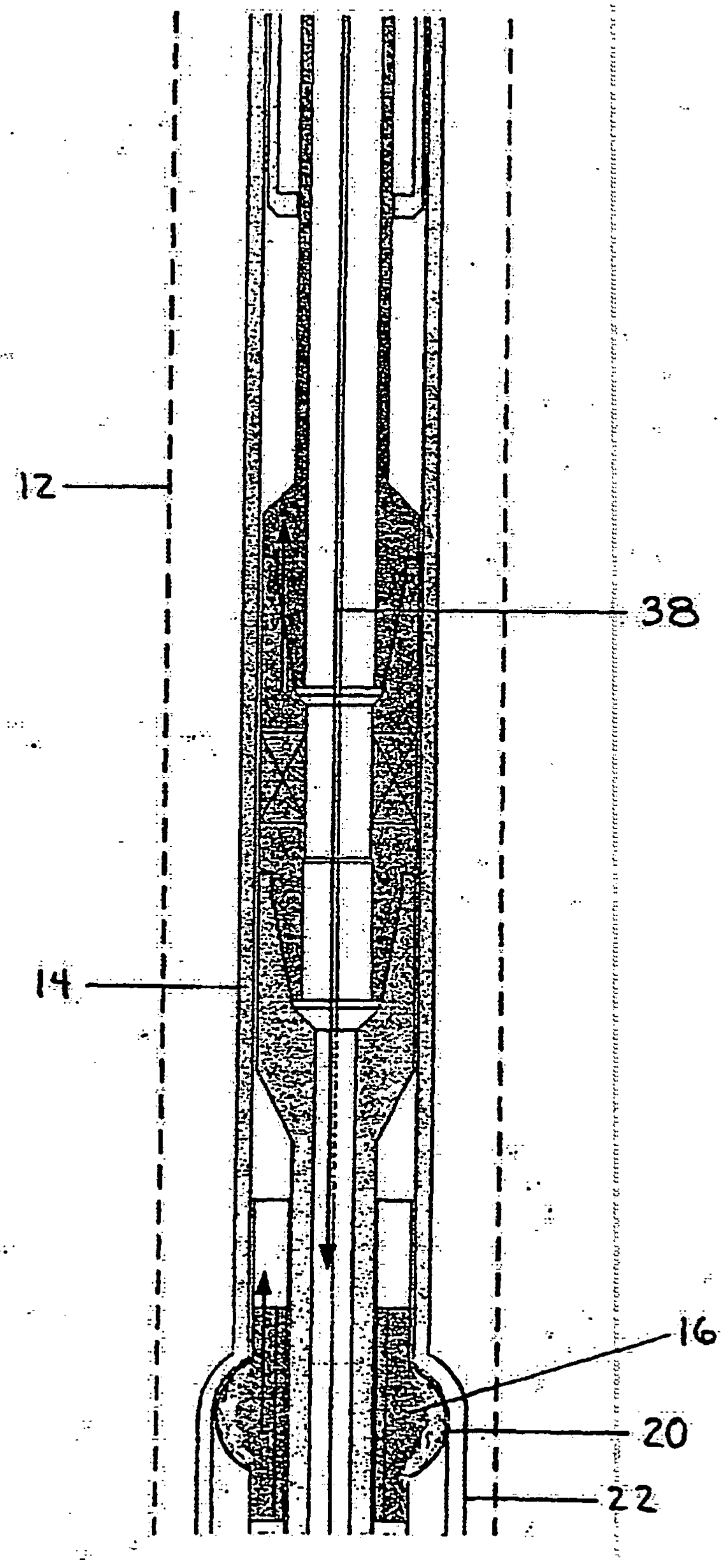


Fig. 9c

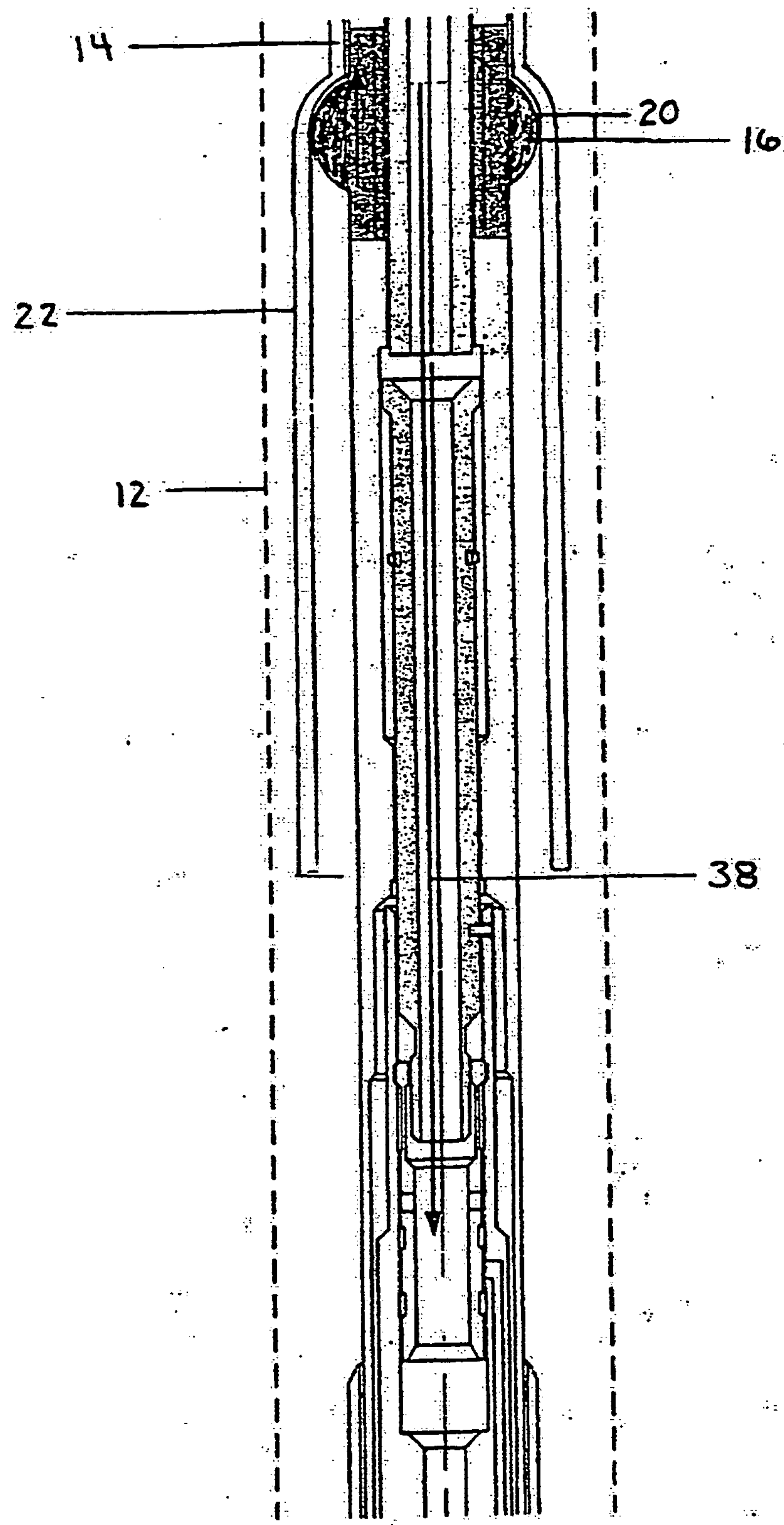


Fig. 9d

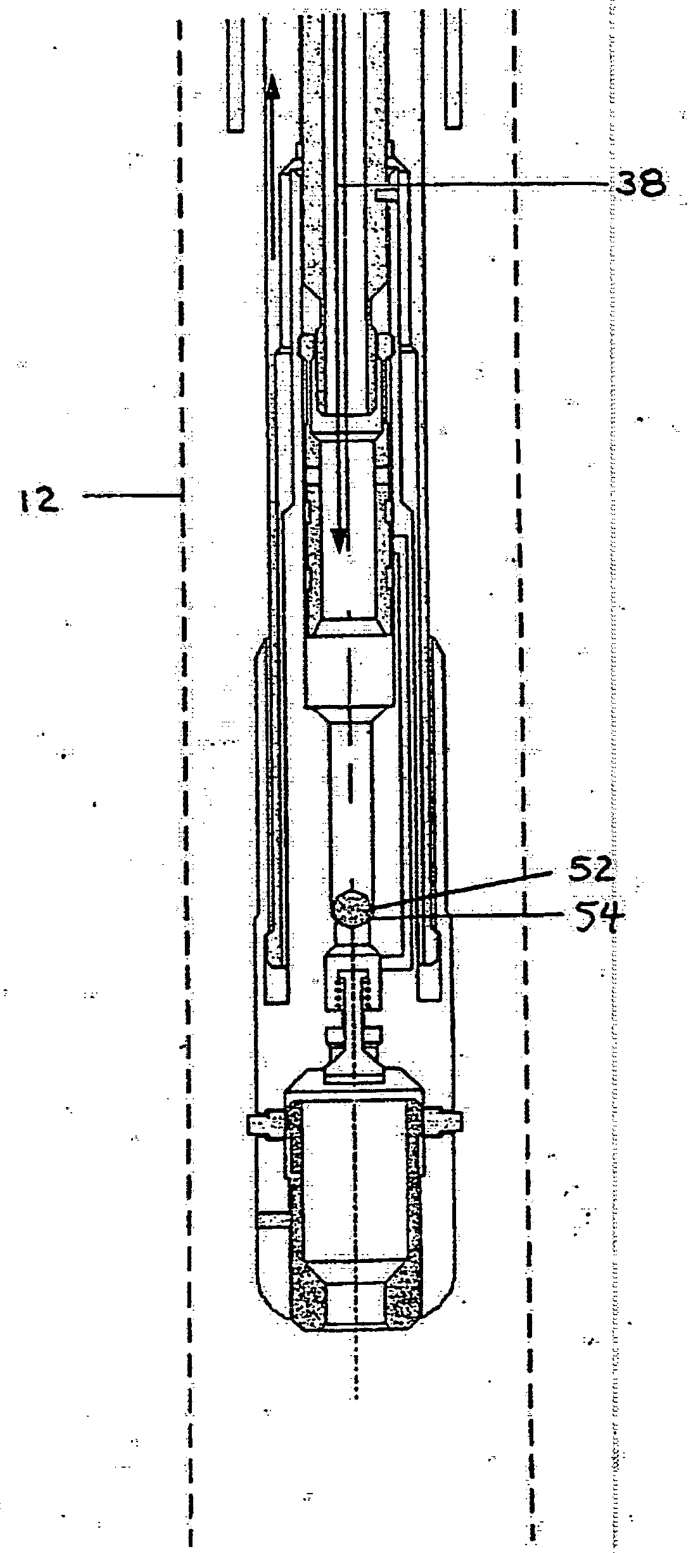


Fig. 9e

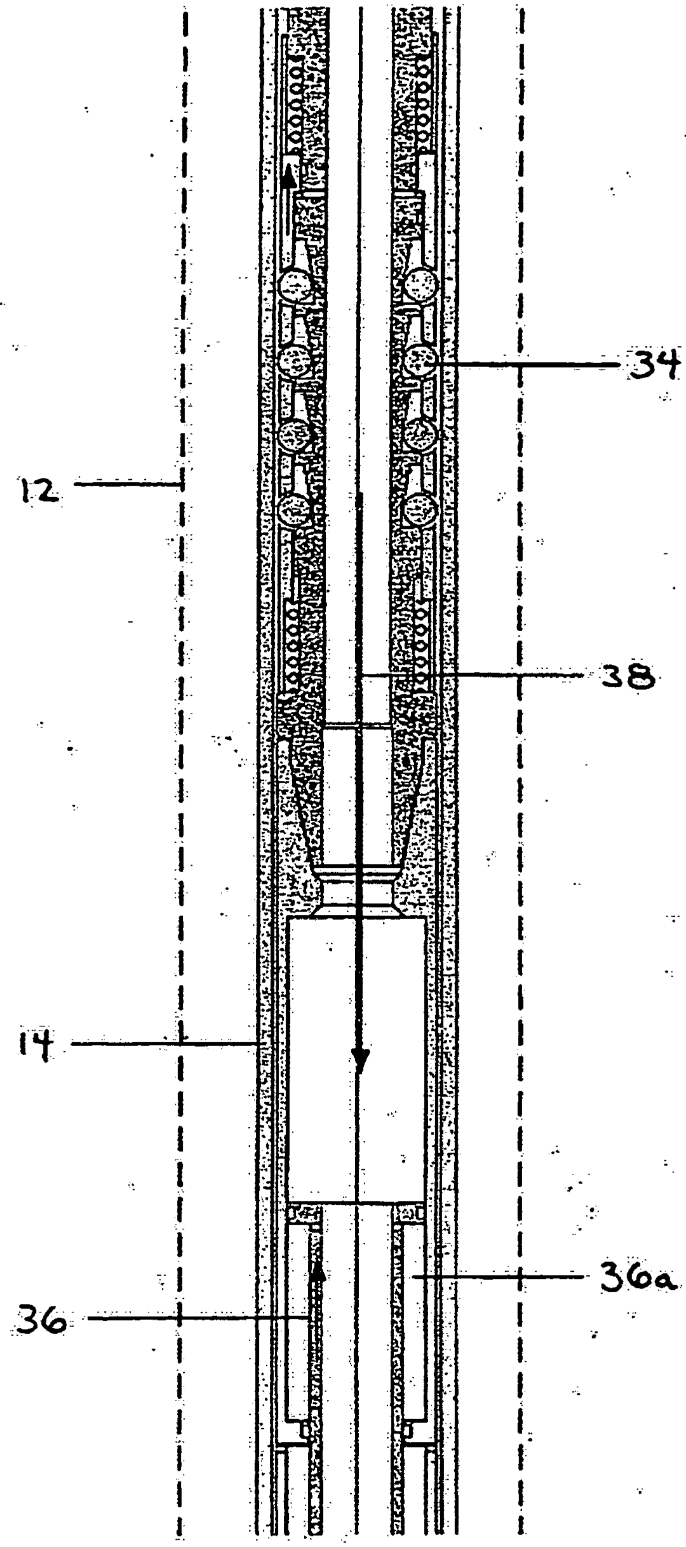


Fig. 10a

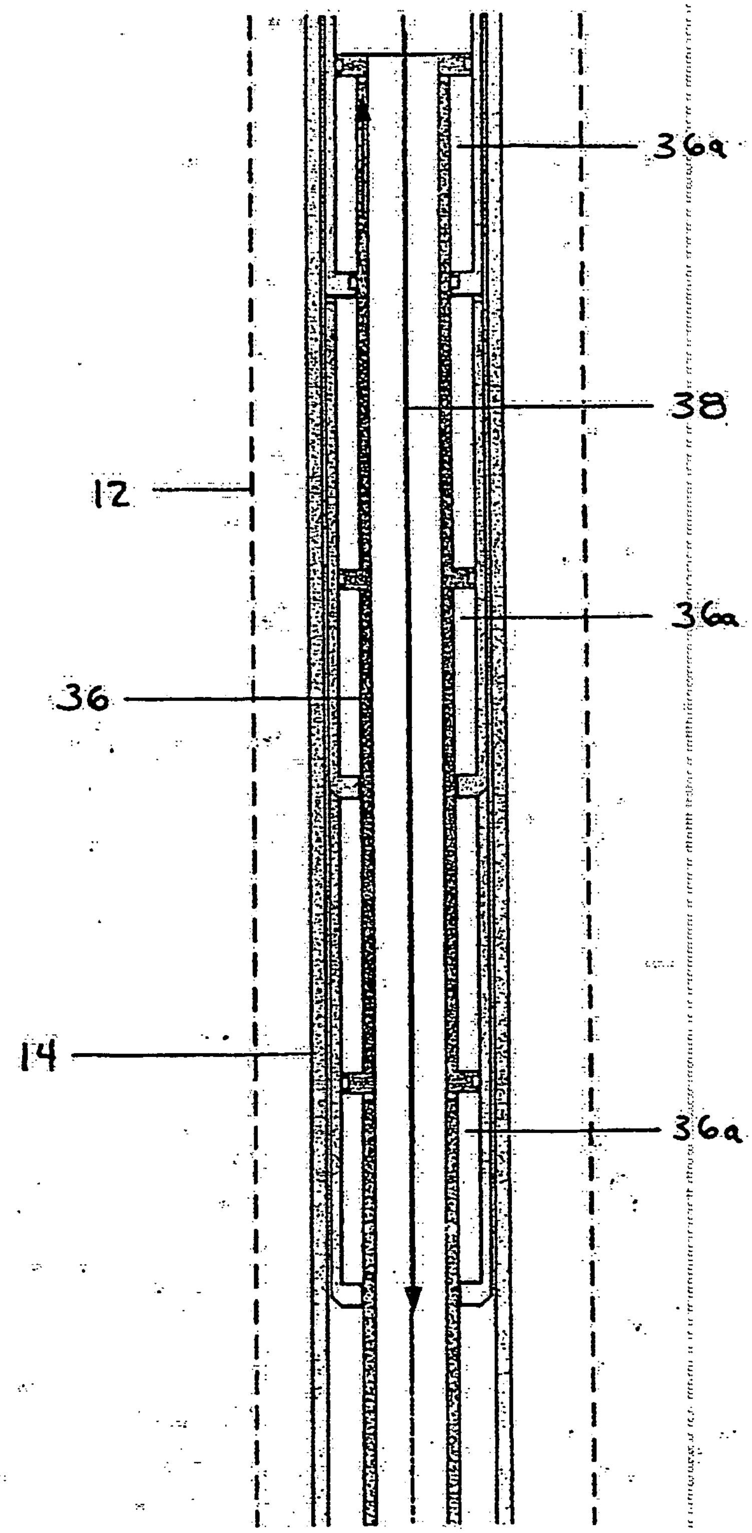


Fig. 10b

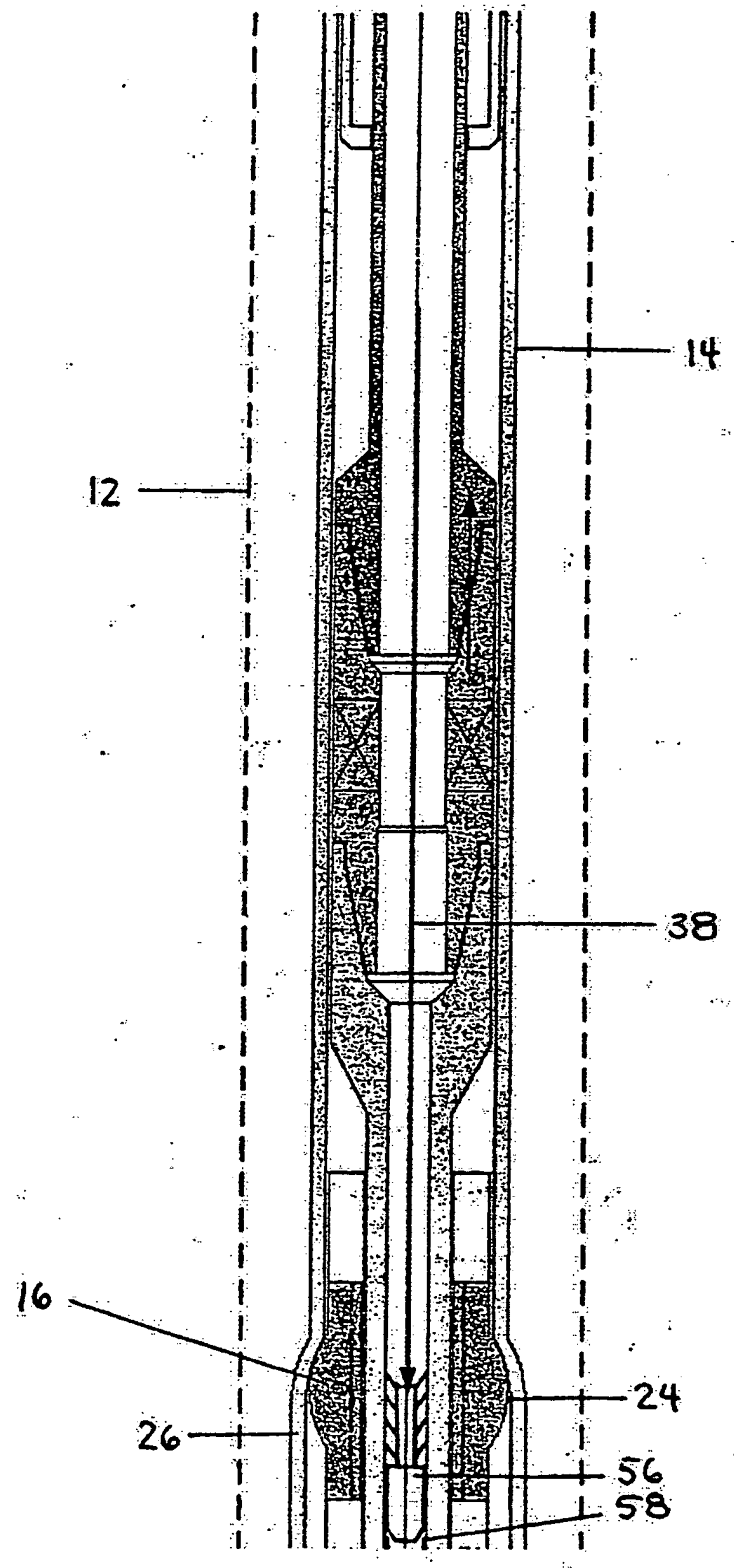


Fig. 10c

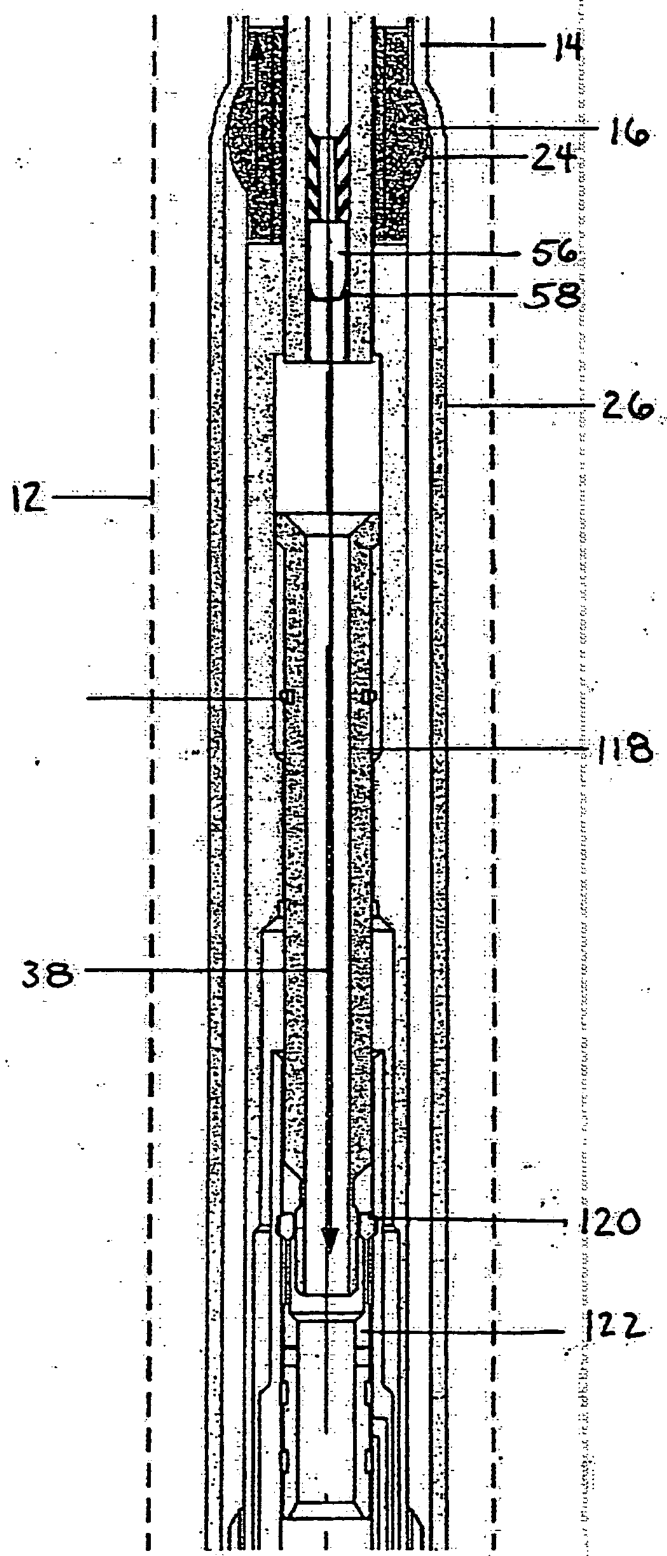


Fig. 10d

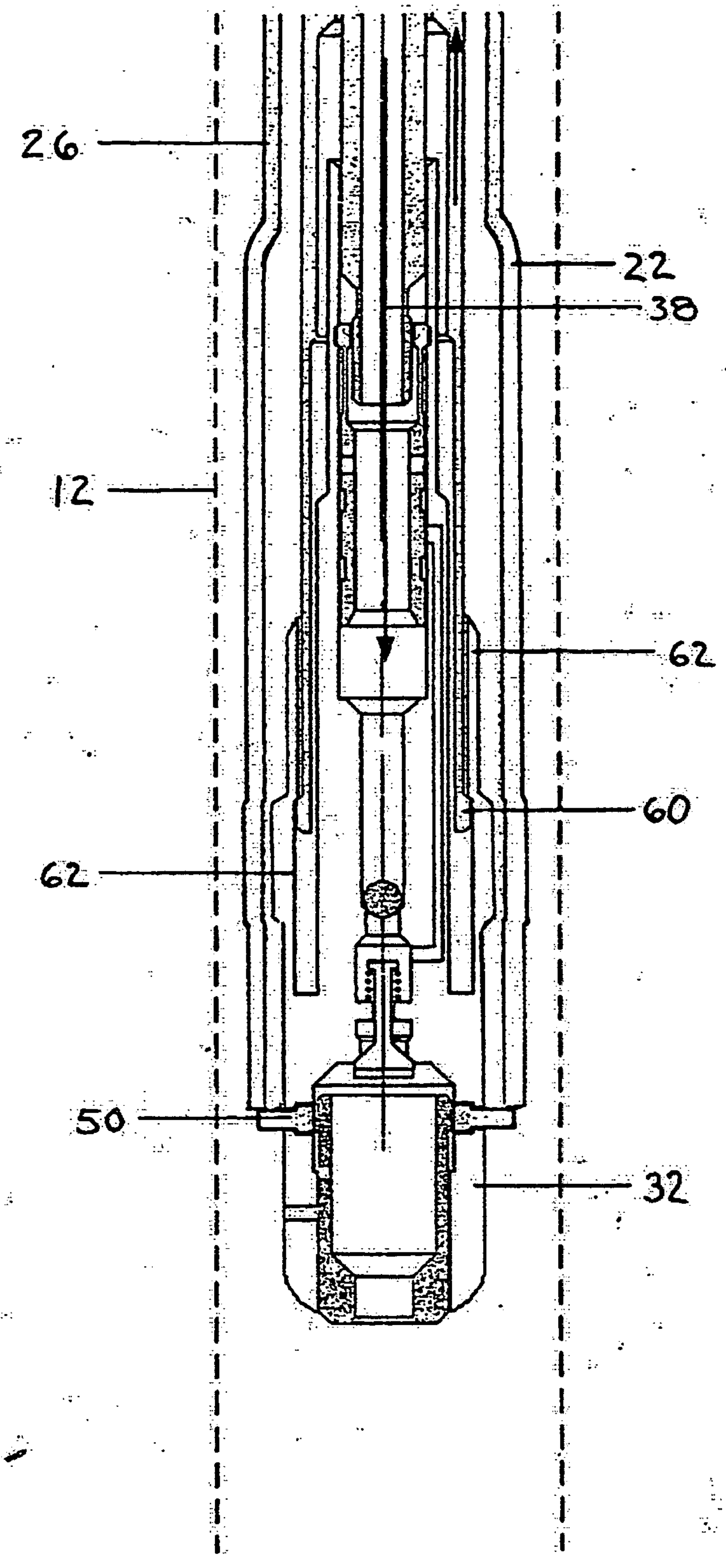
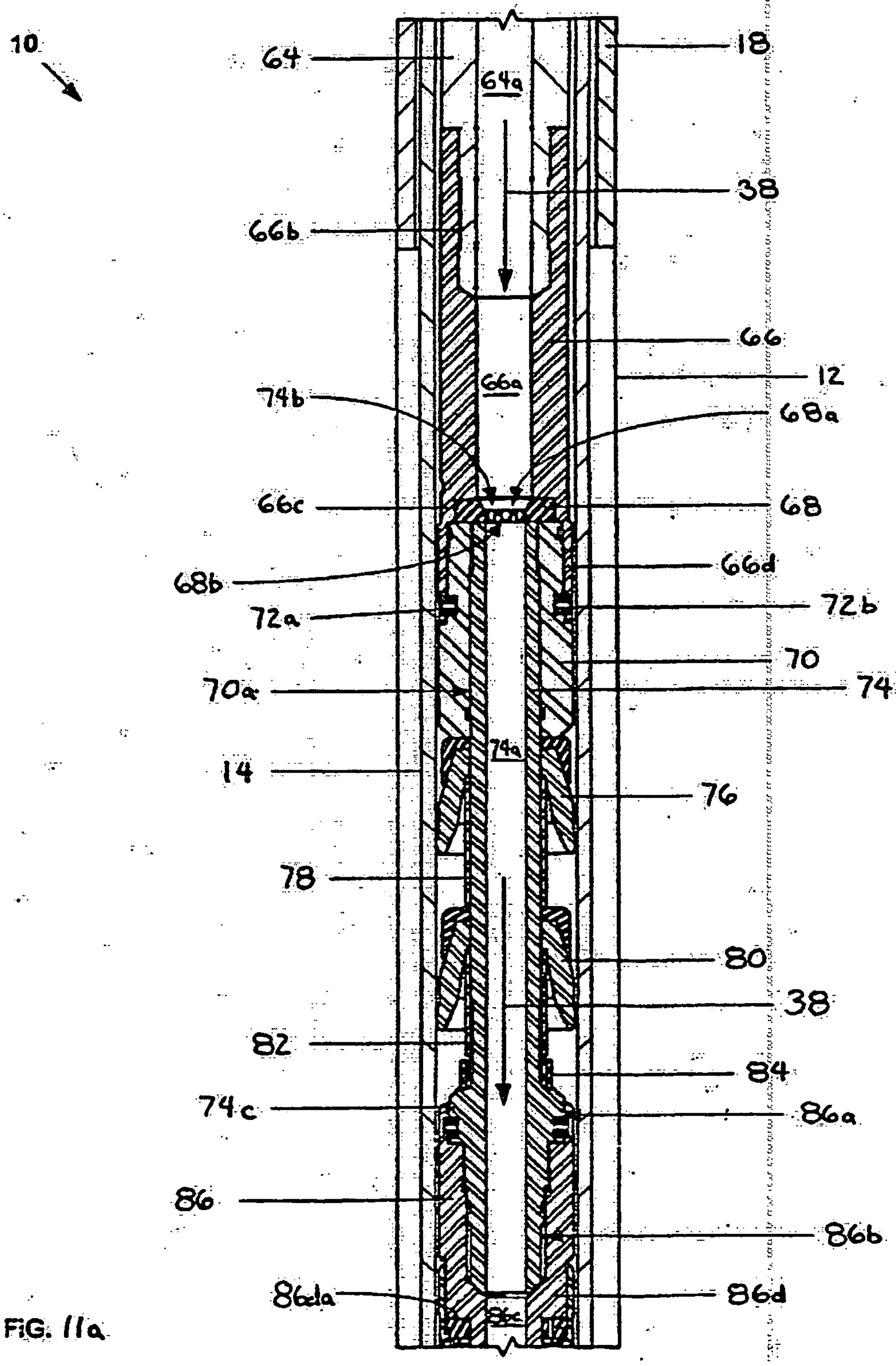


Fig. 10e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66d
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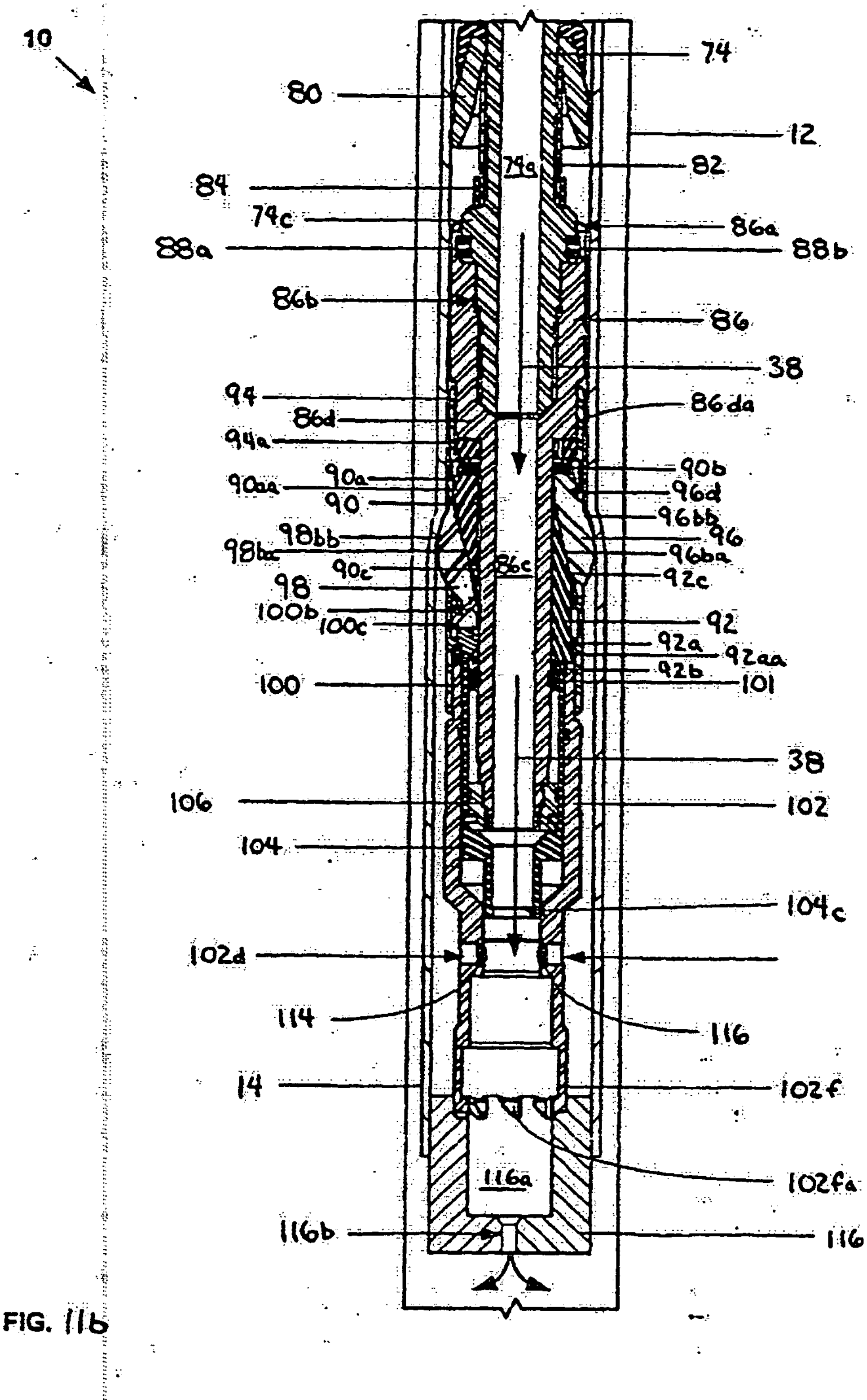
72b
70
70a
74
74a
14
76
78
80
38
82
84
74c
86a
86
86b
86da
86c
86d

FIG. 11a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98bc
96ba
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86c
92c
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100b
100c
92
92a
92aa
92b
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101
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106
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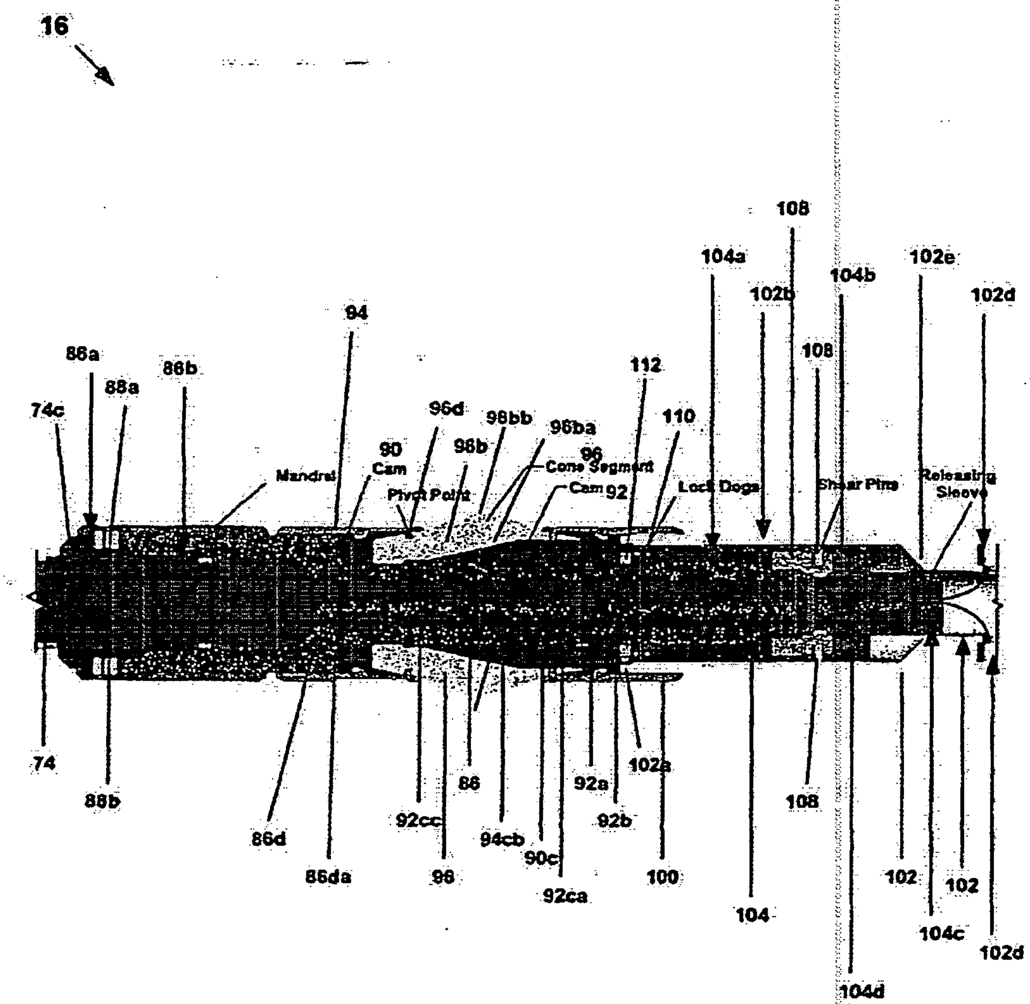
102d
114
116
14
102f
116a
102fa
116b
116

FIG. 11b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102e
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96ba
96b
90
Cam
Mandrel
Pivot Point
Cone Segment
Cam 92
Lock Dogs
Shear Pins
Releasing Sleeve
74
88b
86d
86da
92cc
98
86
94cb
90c
92ca
92a
92b
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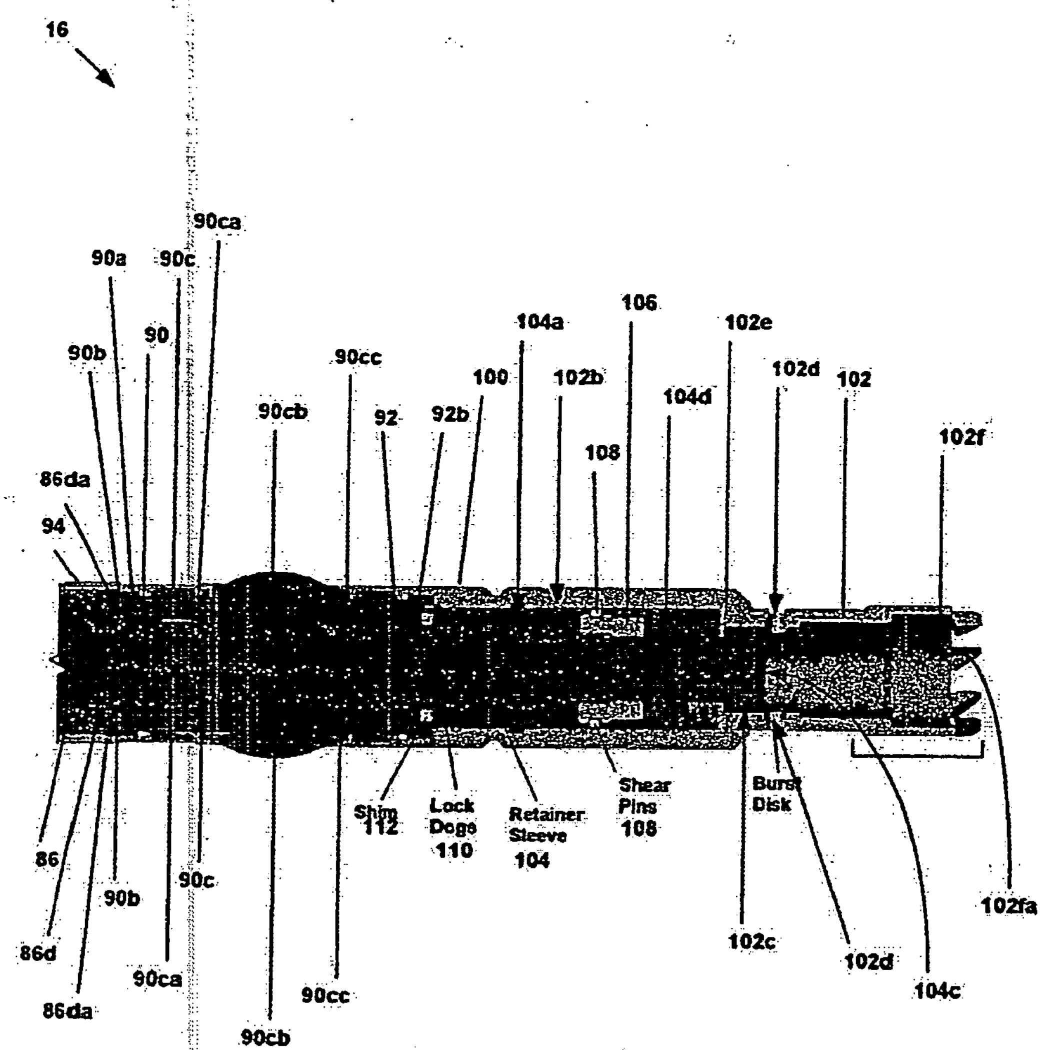
104
108
102
102
104c
102d
104d

FIG. 12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102
102f
86da
94
Shim
112
Lock
Dogs
110
Retainer
Sleeve
104
Shear
Pins
108
Burst
Disk
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90c
86d
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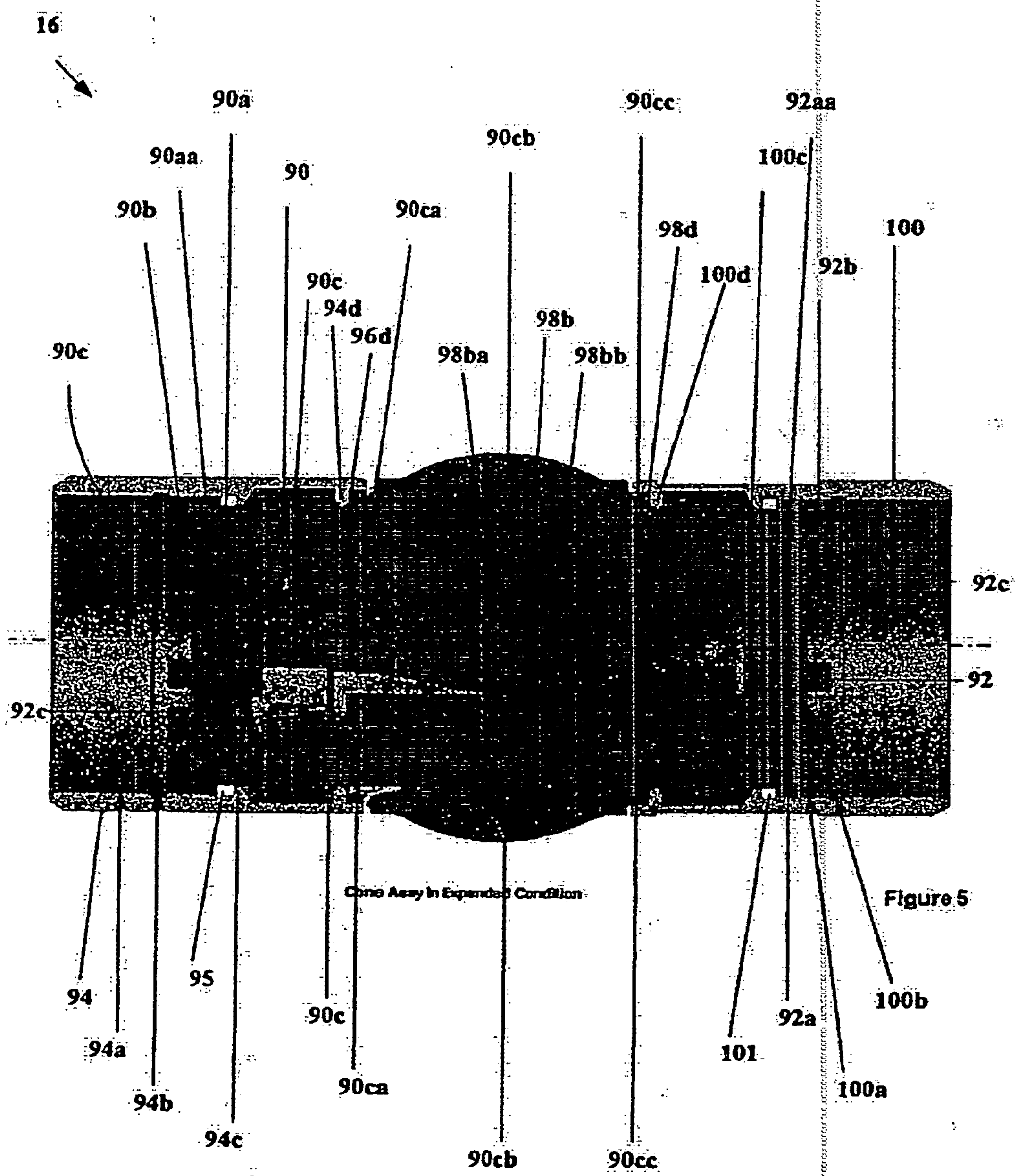
86da
90cb
90cc
102c
102d
104c
102fa

FIG. 13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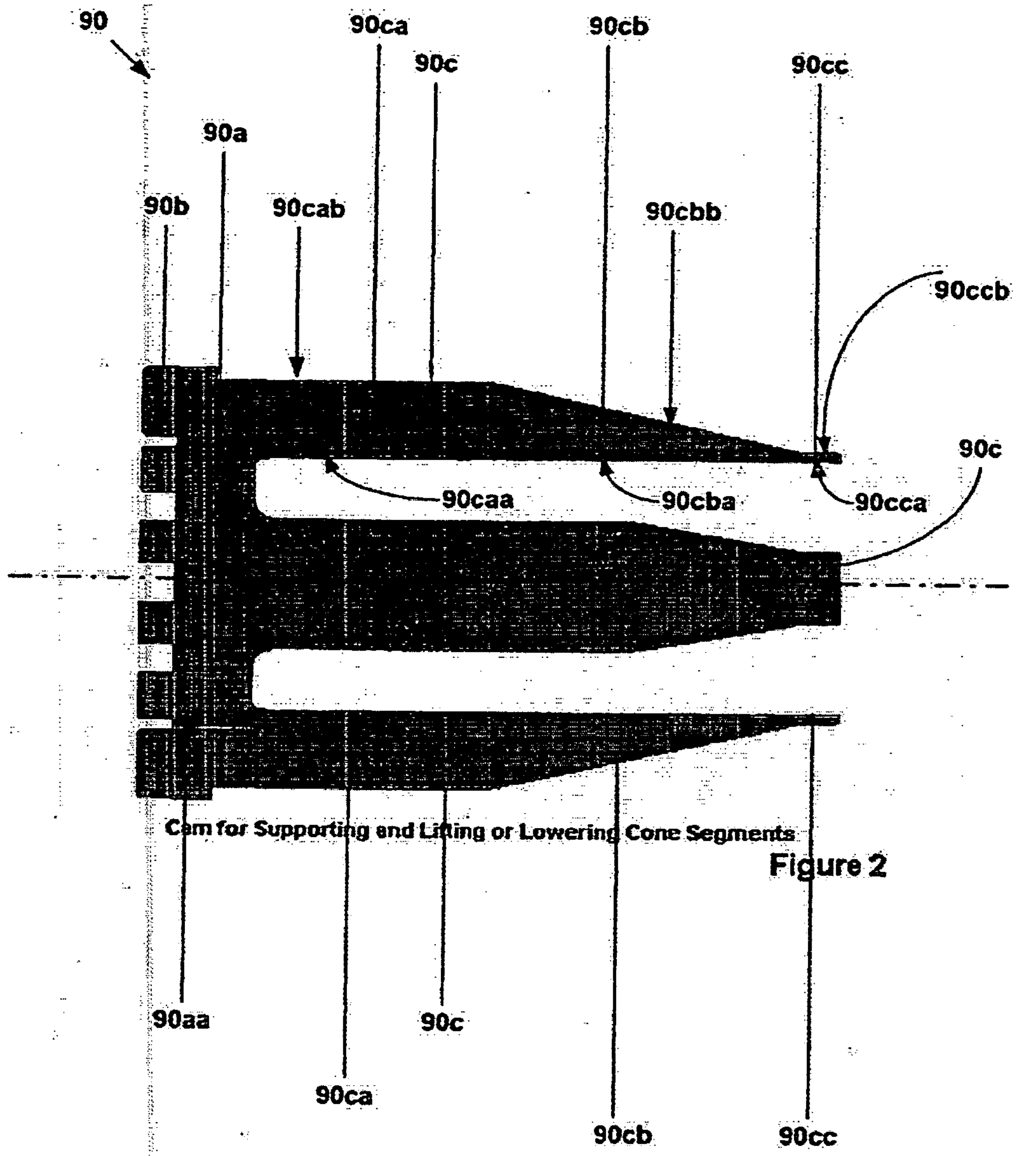
100
100d
92b
90c
94d
98b
96d
90c
98ba
98bb
92c
92
92c
Cone Assy in Expanded Condition
Figure 5
94
95
90c
92a
100b
94a
101
94b
90ca
100a
94c
90cb
90cc

FIG. 14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90ccb
90c
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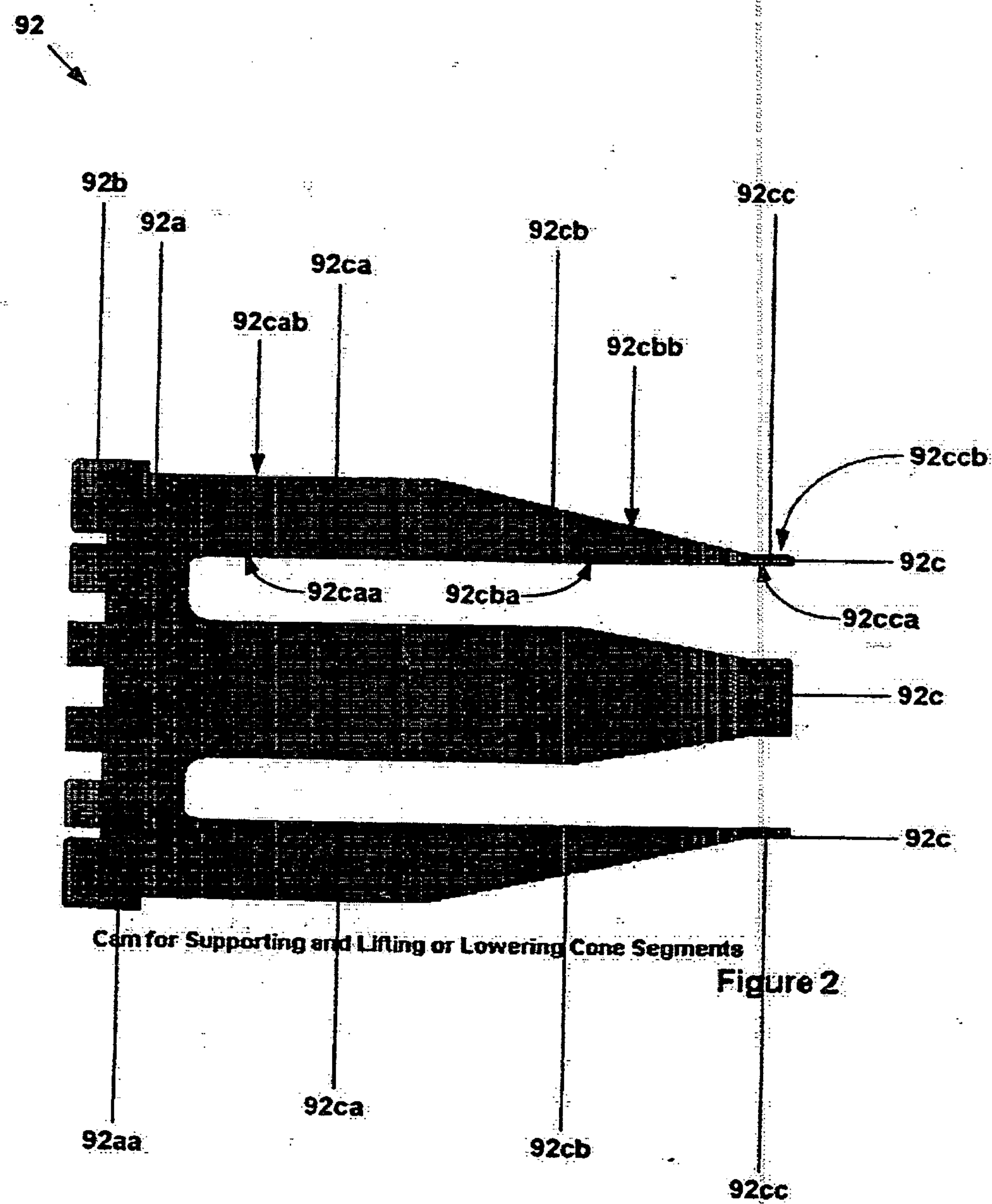
90cba
90cca
Cam for Supporting and Lifting or Lowering Cone Segments
Figure 2
90aa
90c
90ca
90cb
90cc

FIG. 15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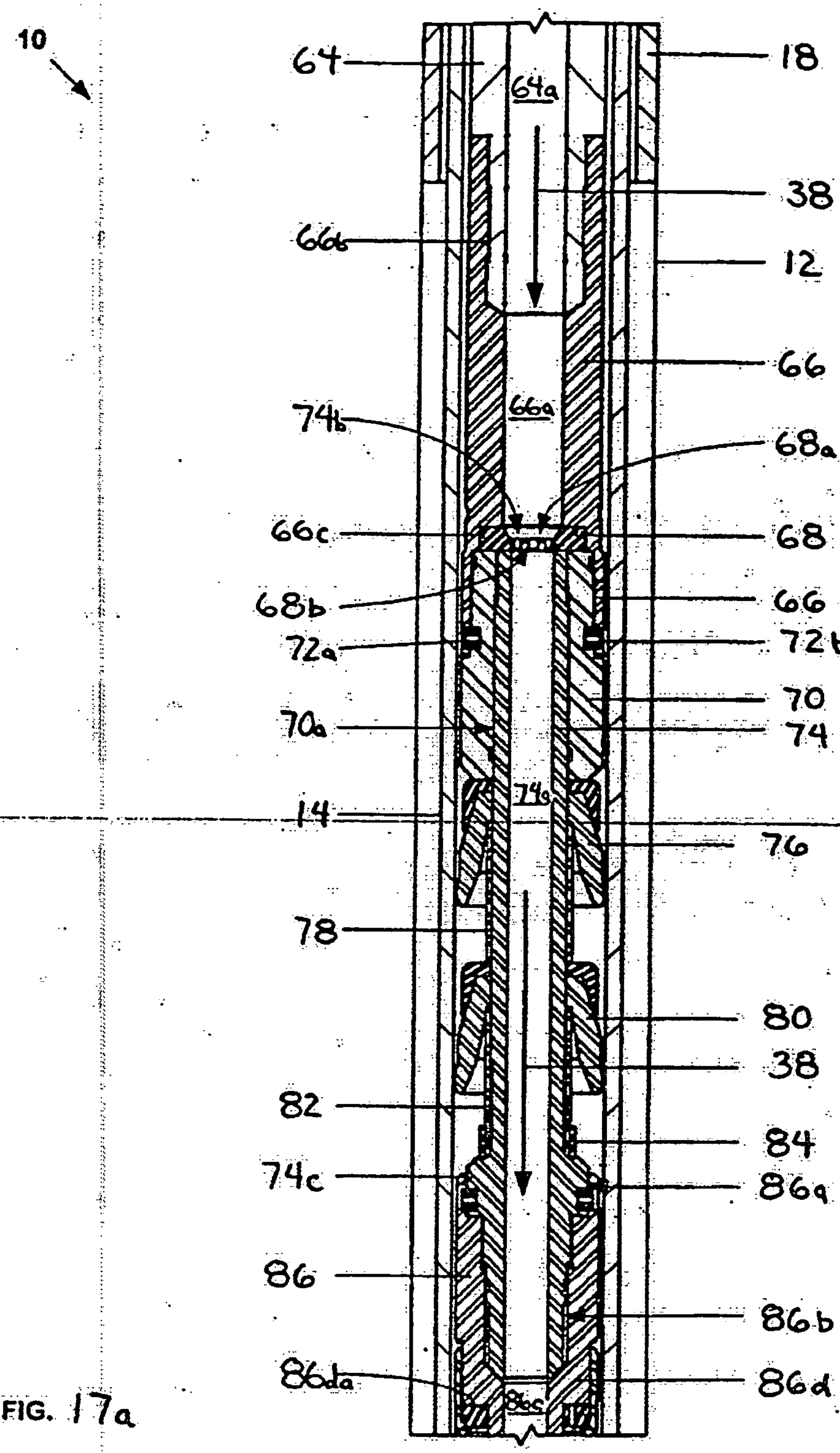
92cab
92cbb
92ccb
92c
92caa
92cba
92cca
92c
92c
Cam for Supporting and Lifting or Lowering Cone Segments
Figure 2
92aa
92ca
92cb
92cc

FIG. 16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70a
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74a
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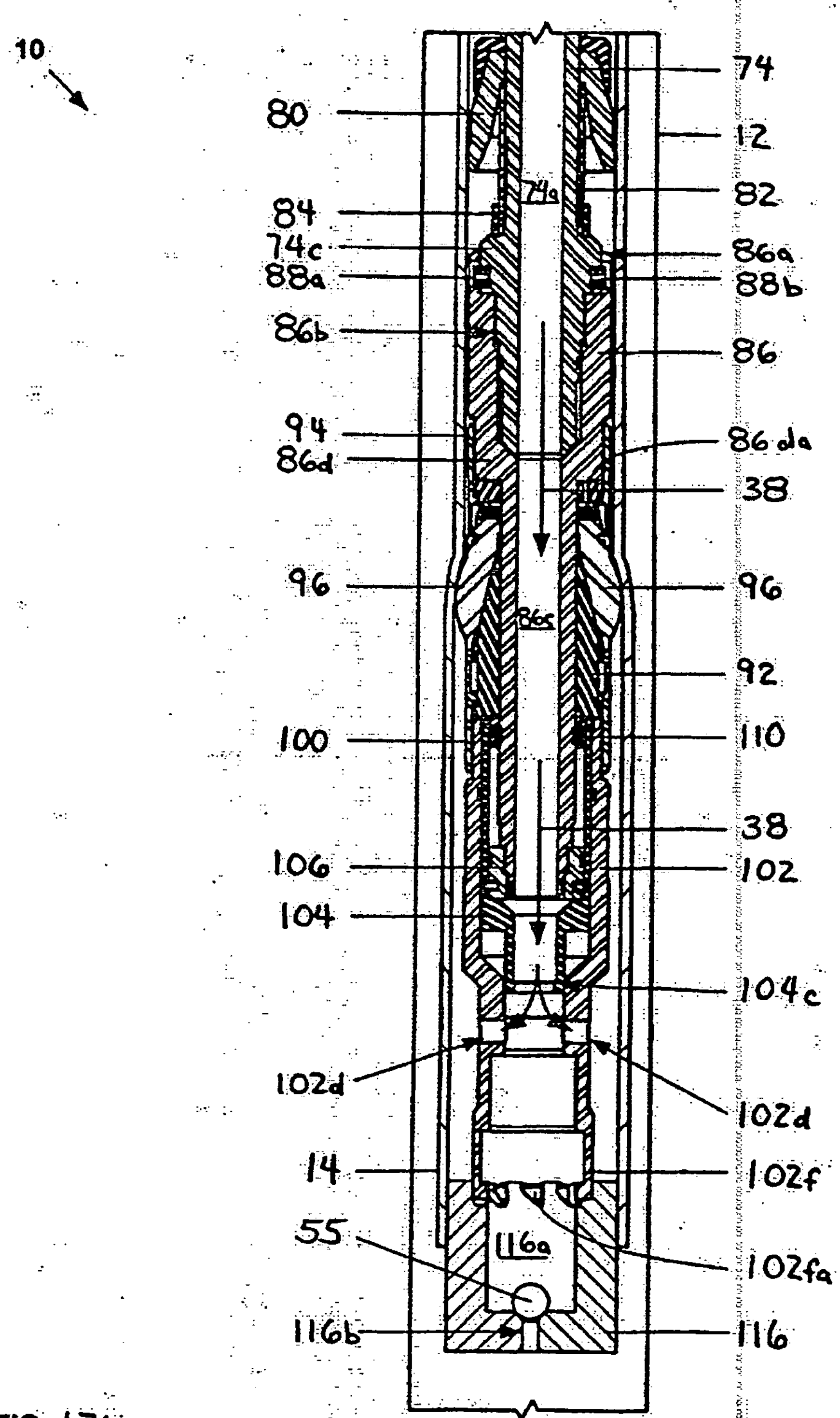
76
78
80
38
82
84
74c
86a
86
86b
86da
86c
86d

FIG. 17a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12
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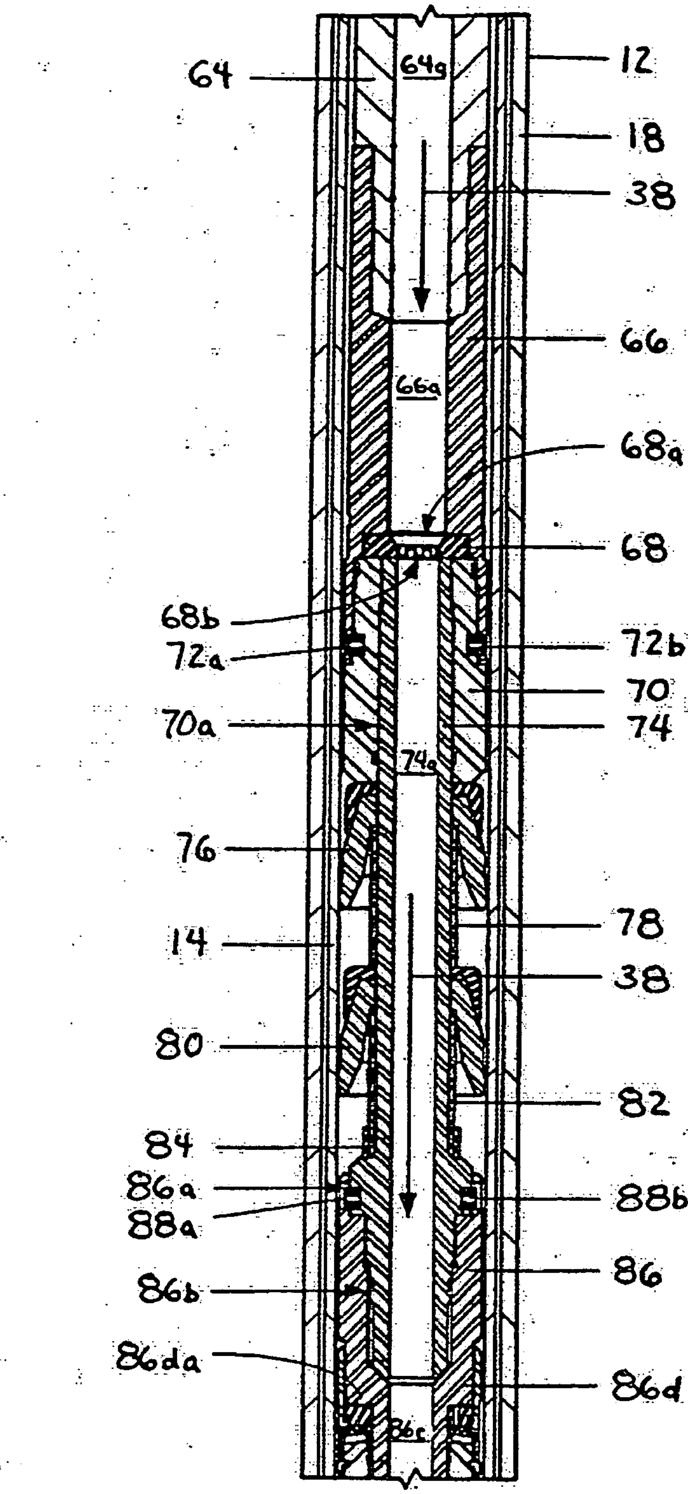
92
110
38
102
104c
102d
102f
102fa
116

FIG. 17b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88a
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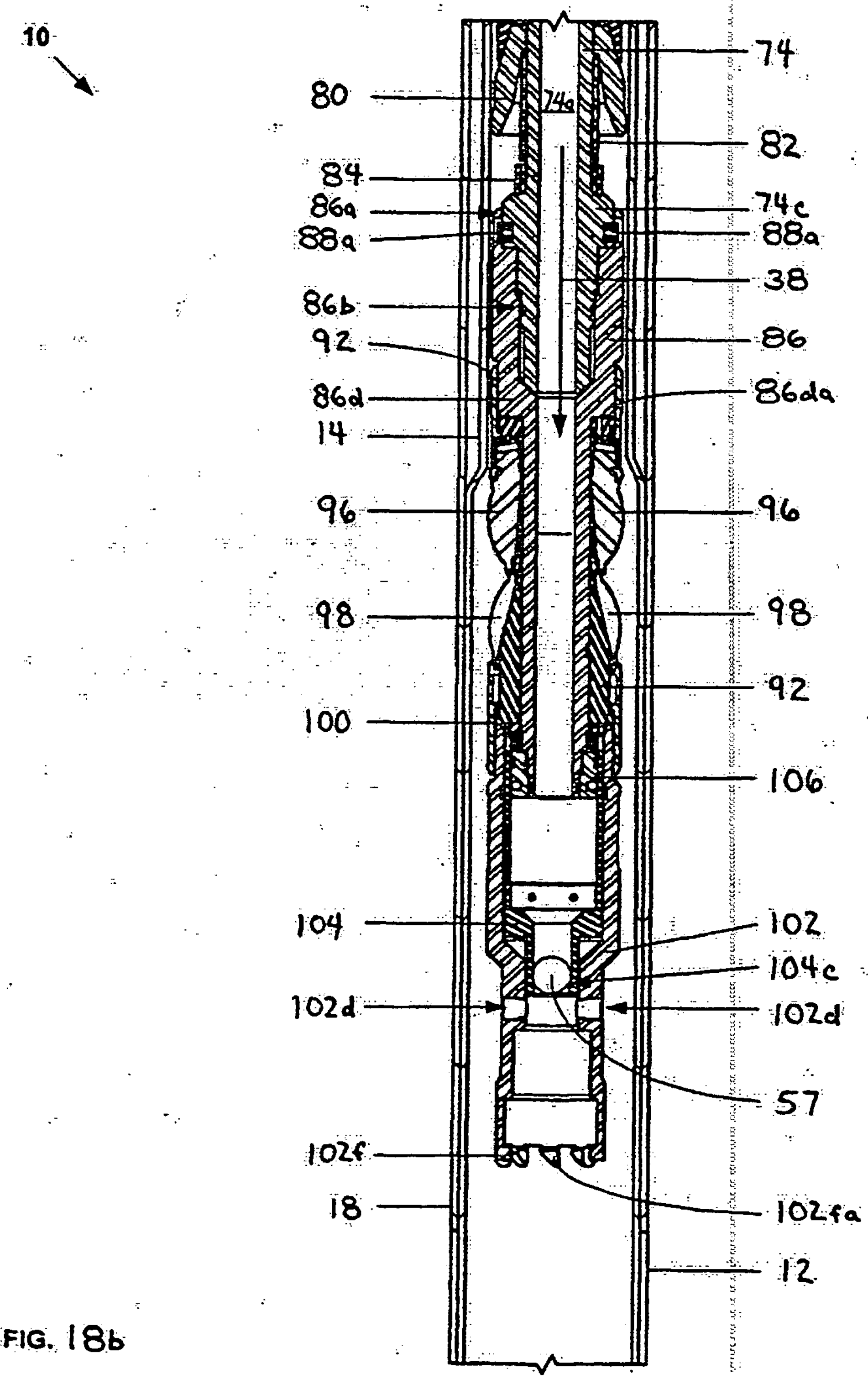
86b
86da
86d
86c

FIG 18a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104c
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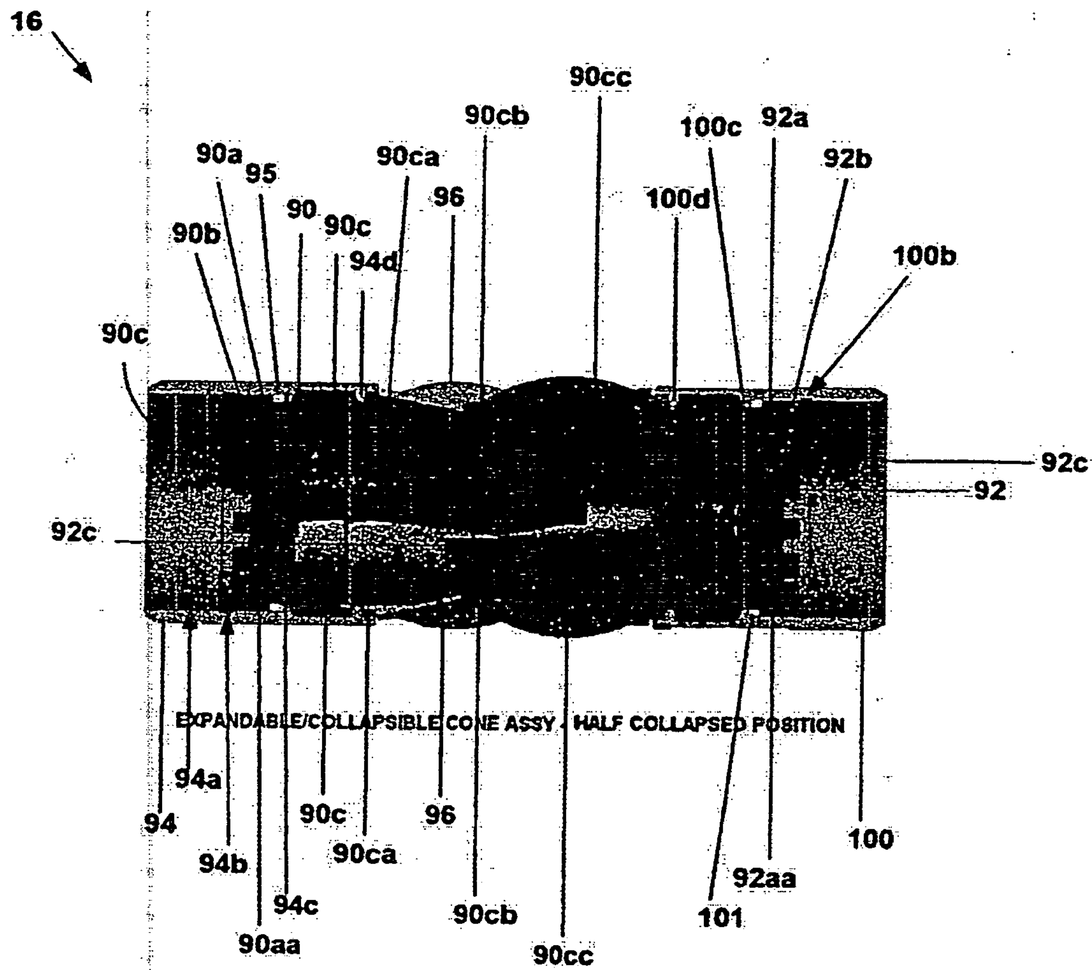
57
102f
102fa
18
12

FIG. 18b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90c
92c
92
92c
EXPANDABLE/COLLAPSIBLE CONE ASSY - HALF COLLAPSED POSITION
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94
90c
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100
94b
90ca
92aa
94c
90cb
101
90aa
90cc

FIG. 19

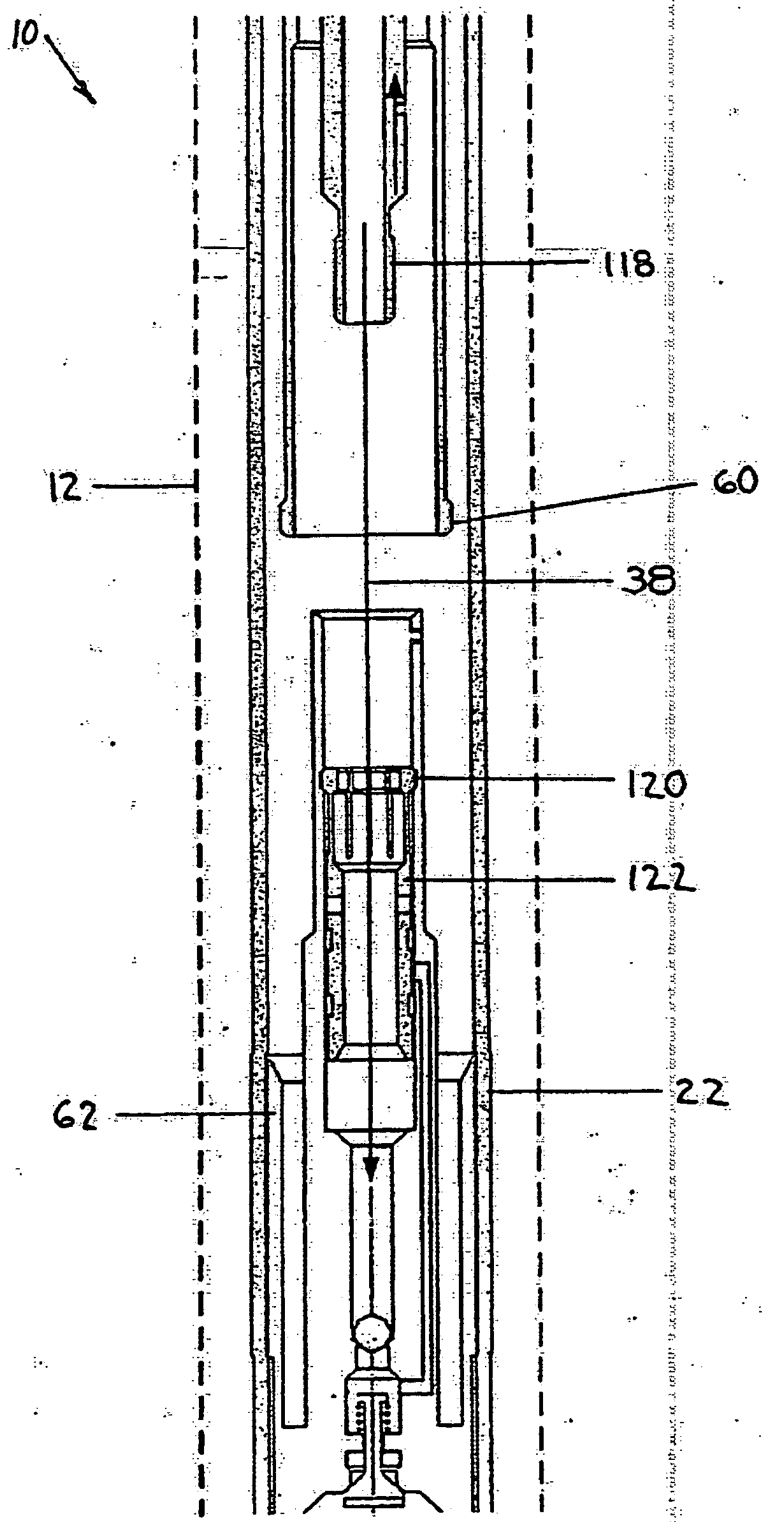

Fig. 20a

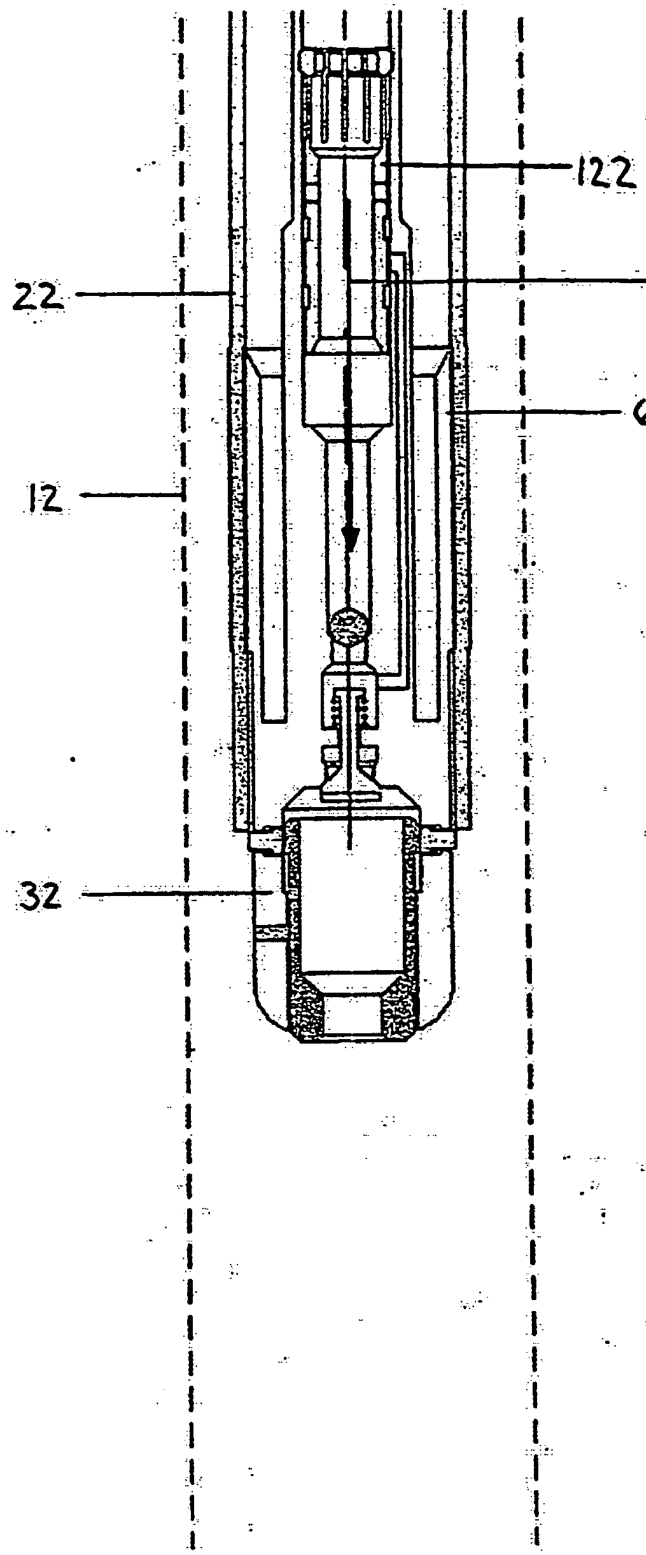

Fig. 20b

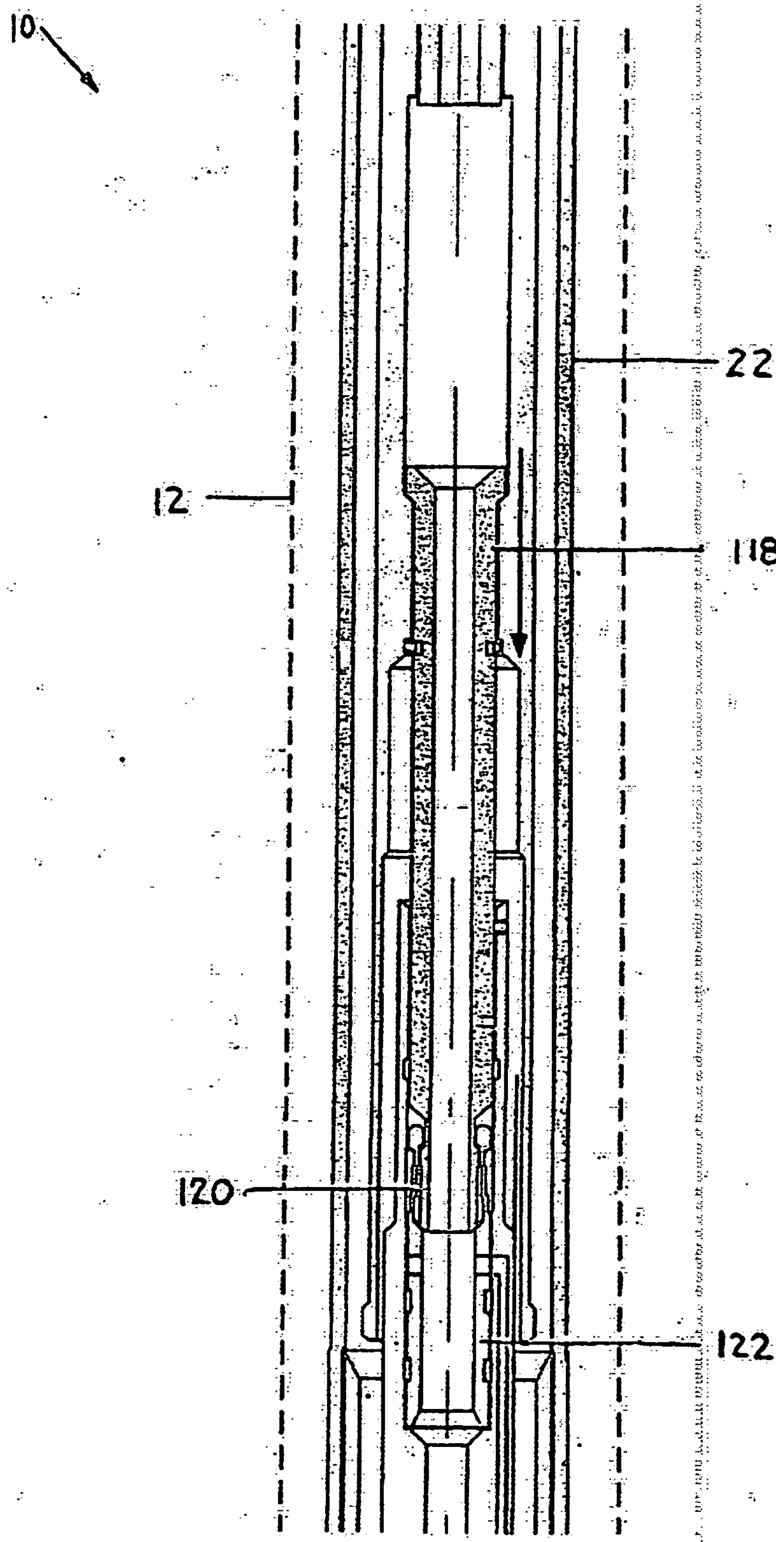

Fig. 21a

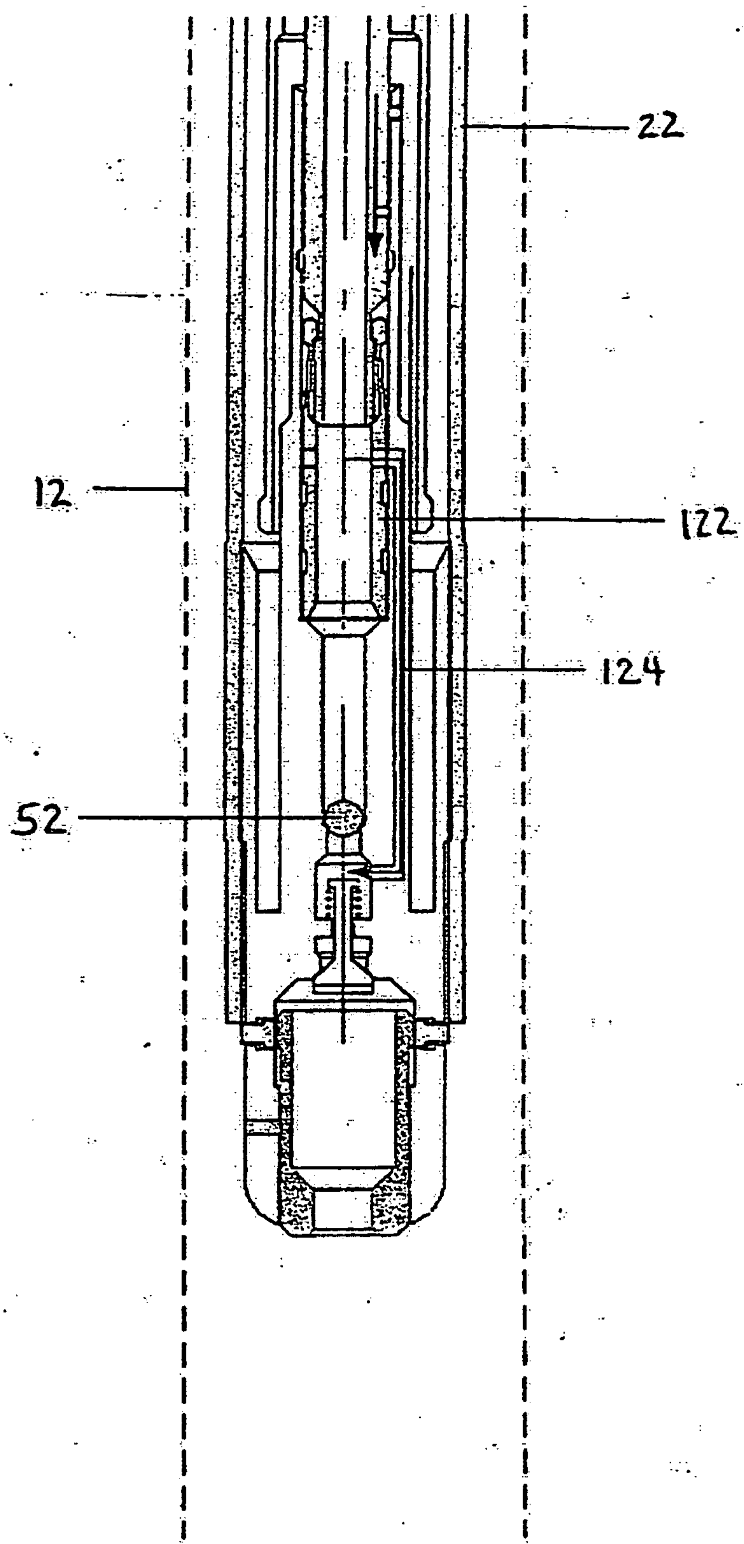

Fig. 21b

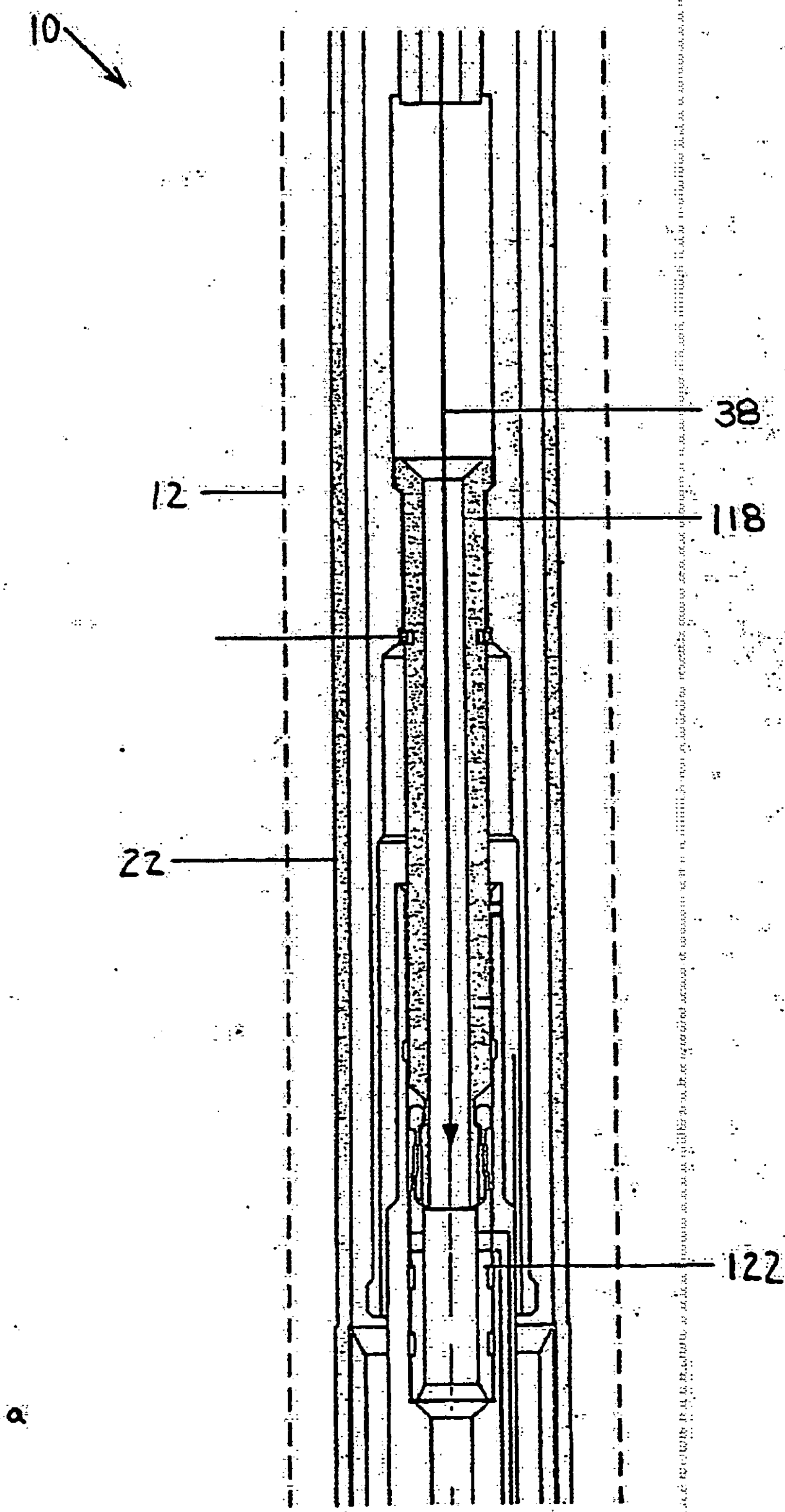

Fig. 22a

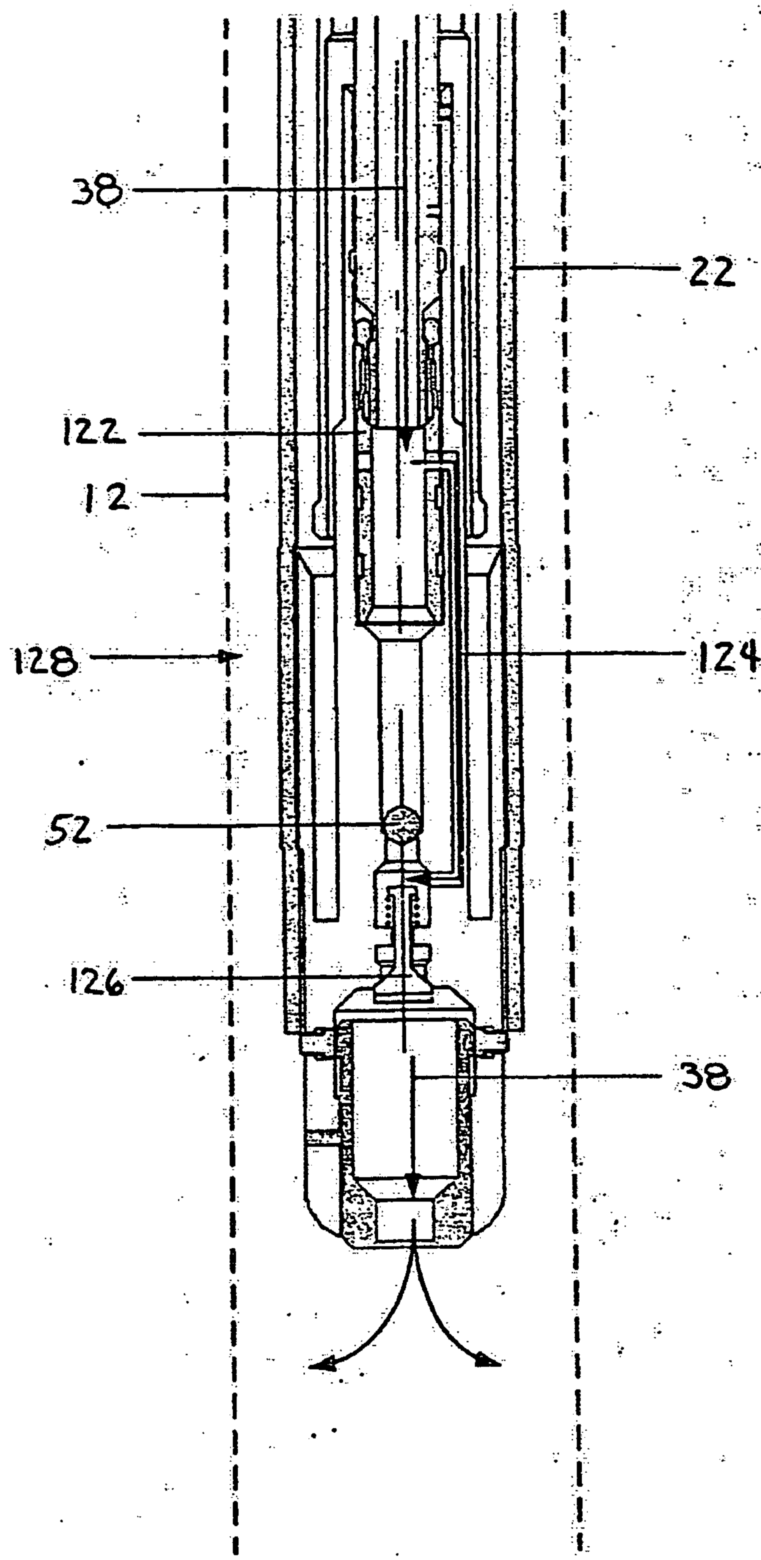

Fig. 22b

REFERENCES CITED IN THE DESCRIPTION

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